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(12) **United States Patent**  
**Chida**

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(54) **LIGHT-EMITTING DEVICE, MODULE, ELECTRONIC DEVICE, AND METHOD FOR MANUFACTURING LIGHT-EMITTING DEVICE**

(71) Applicant: **Semiconductor Energy Laboratory Co., Ltd.**, Kanagawa-ken (JP)

(72) Inventor: **Akihiro Chida**, Kanagawa (JP)

(73) Assignee: **Semiconductor Energy Laboratory Co., Ltd.**

(\*) Notice: Subject to any disclaimer, the term of this patent is extended or adjusted under 35 U.S.C. 154(b) by 15 days.

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(30) **Foreign Application Priority Data**

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(51) **Int. Cl.**  
**H01L 51/52** (2006.01)  
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(Continued)

(52) **U.S. Cl.**  
CPC ..... **H01L 51/5246** (2013.01); **H01L 27/322** (2013.01); **H01L 27/3262** (2013.01);  
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(58) **Field of Classification Search**  
None  
See application file for complete search history.

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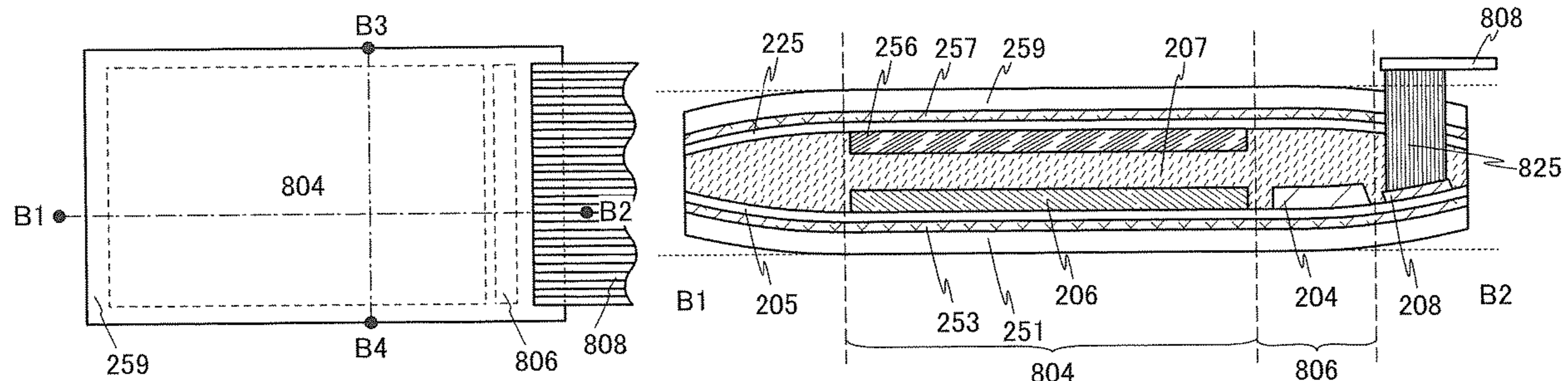
*Primary Examiner* — J. E. Schoenholtz

(74) *Attorney, Agent, or Firm* — Husch Blackwell LLP

(57) **ABSTRACT**

A light-emitting element, a bonding layer, and a frame-like partition are formed over a substrate. The partition is provided to surround the bonding layer and the light-emitting element, with a gap left between the partition and the bonding layer. A pair of substrates overlap with each other under a reduced-pressure atmosphere and then exposed to an air atmosphere or a pressurized atmosphere, whereby the reduced-pressure state of a space surrounded by the pair of substrates and the partition is maintained and atmospheric pressure is applied to the pair of substrates. Alternatively, a light-emitting element and a bonding layer are formed over a substrate. A pair of substrates overlap with each other, and then, pressure is applied to the bonding layer with the use of a member having a projection before or at the same time as curing of the bonding layer.

**4 Claims, 47 Drawing Sheets**



**Related U.S. Application Data**

continuation of application No. 15/839,059, filed on Dec. 12, 2017, now Pat. No. 10,270,057, which is a continuation of application No. 14/882,918, filed on Oct. 14, 2015, now Pat. No. 9,847,505.

(51) **Int. Cl.**

**H01L 27/32** (2006.01)  
**H01L 51/56** (2006.01)

(52) **U.S. Cl.**

CPC ..... **H01L 27/3276** (2013.01); **H01L 51/0097** (2013.01); **H01L 51/56** (2013.01); **H01L 2227/323** (2013.01); **H01L 2251/5338** (2013.01); **H01L 2251/558** (2013.01); **Y02E 10/549** (2013.01); **Y02P 70/50** (2015.11)

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FIG. 1A

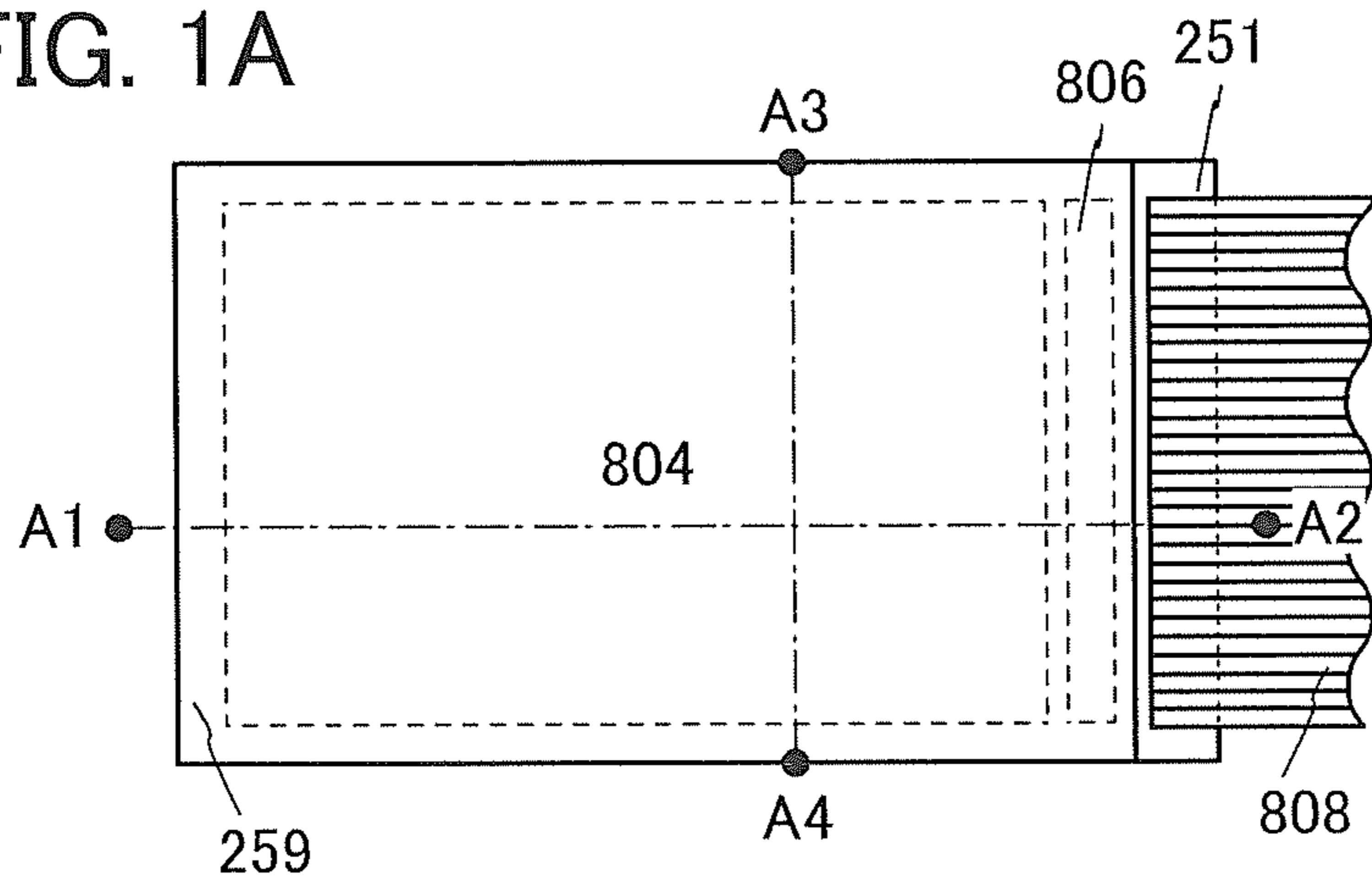


FIG. 1B

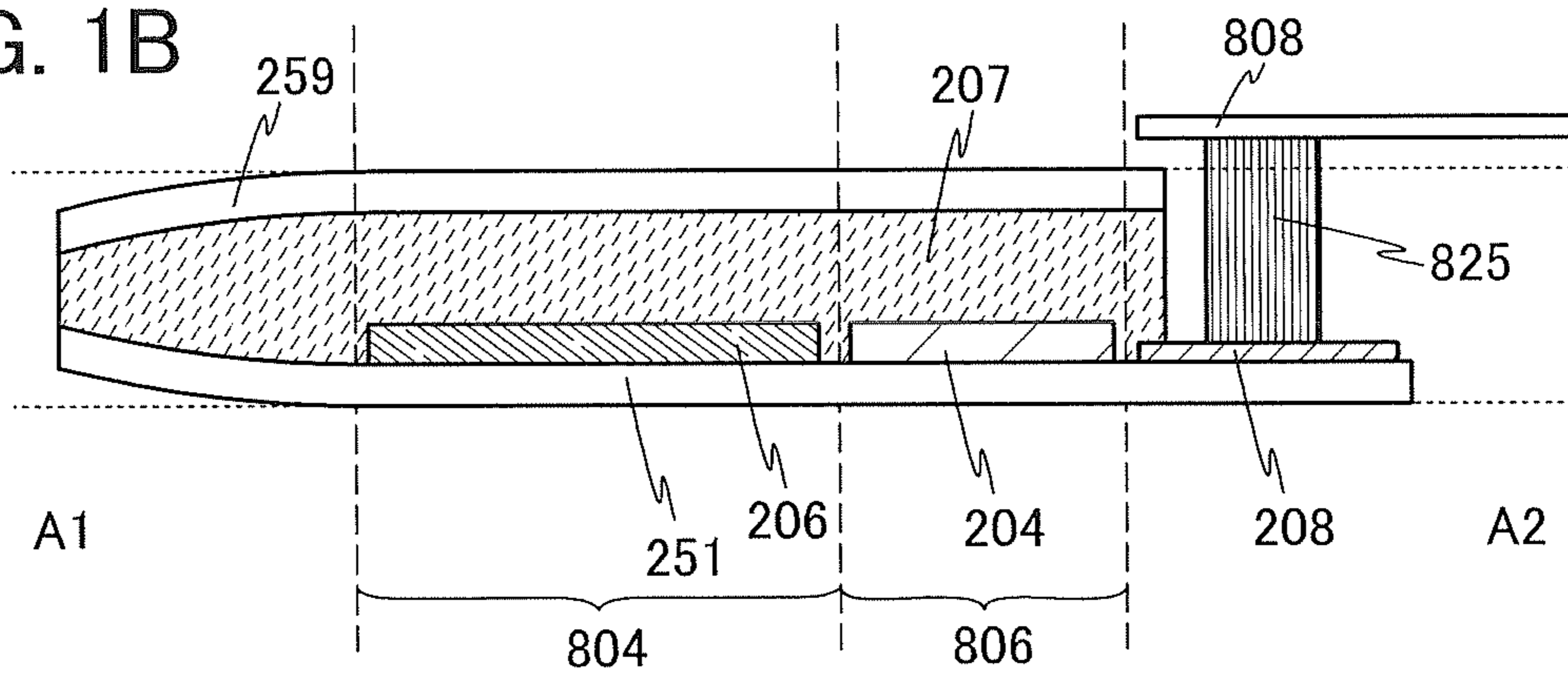


FIG. 1C

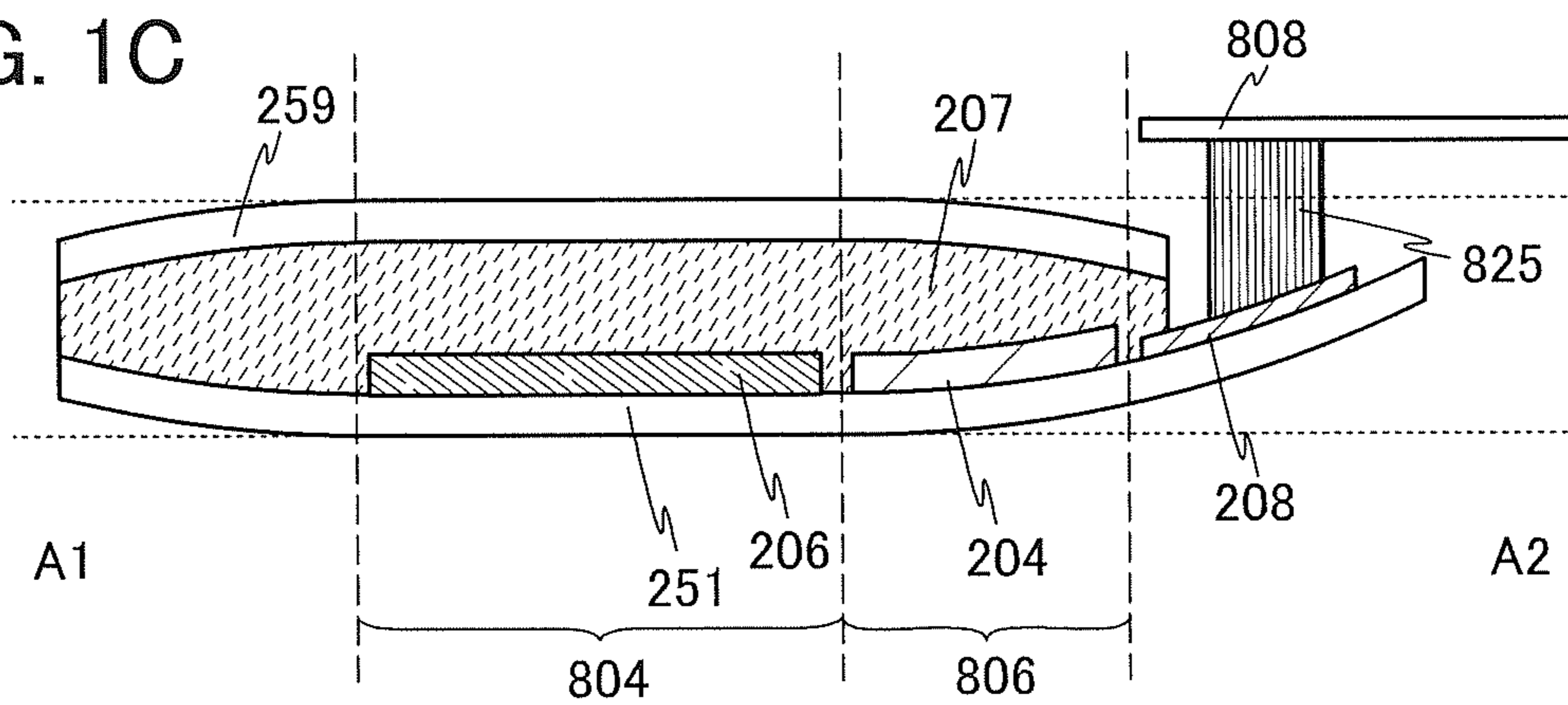


FIG. 1D

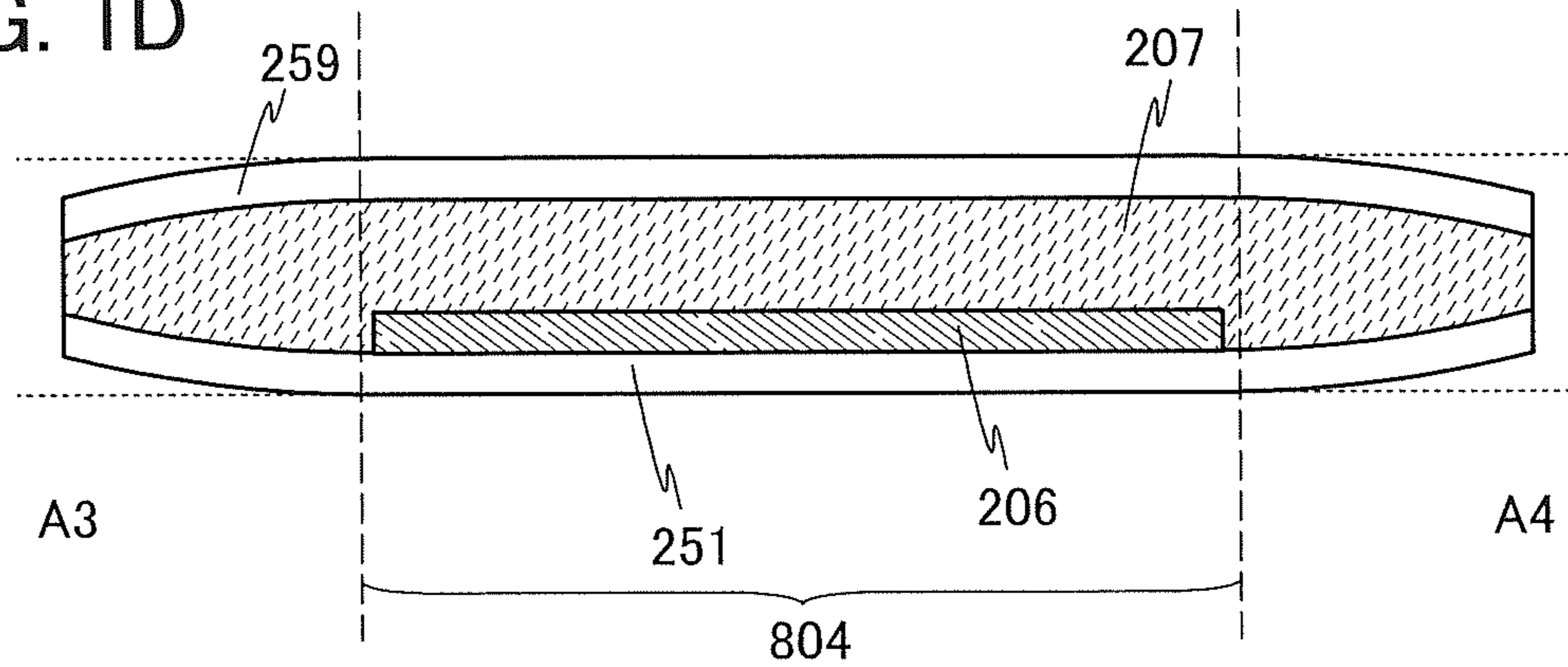


FIG. 2A

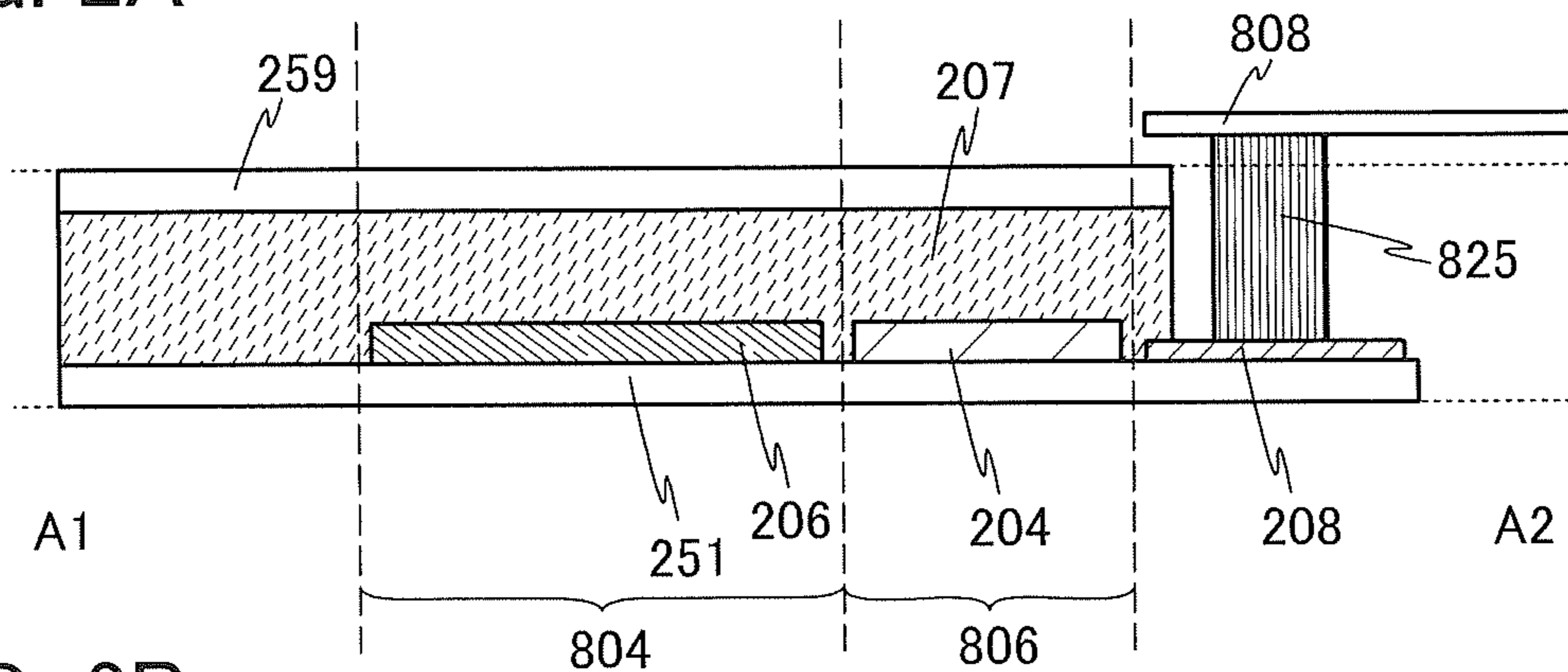


FIG. 2B

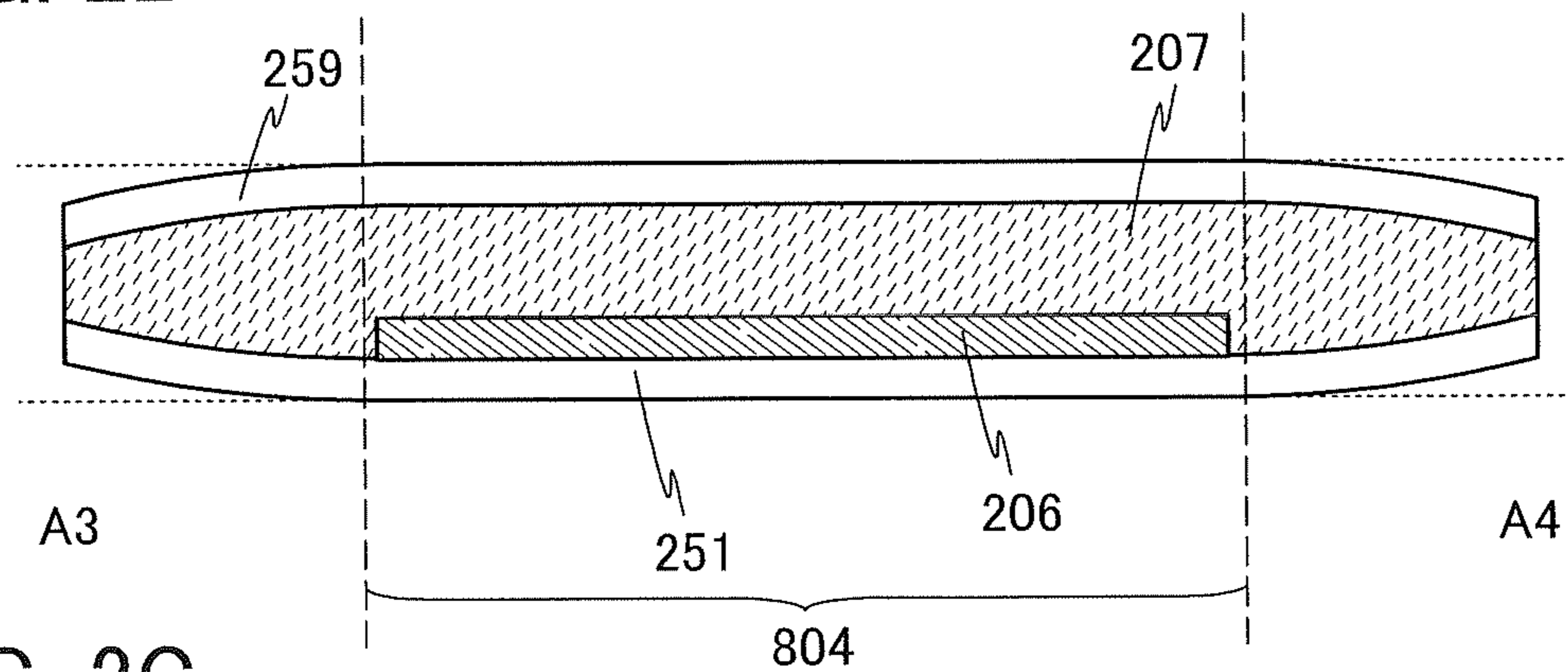


FIG. 2C

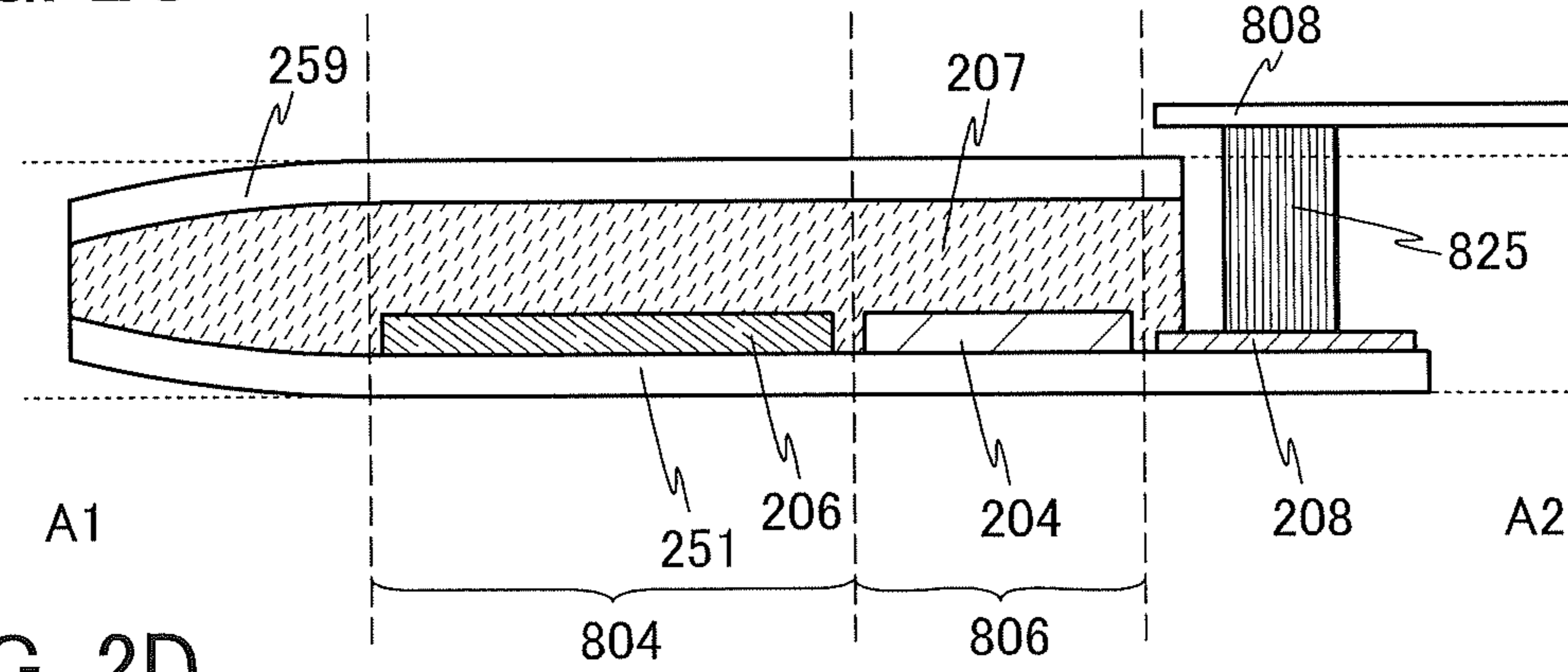


FIG. 2D

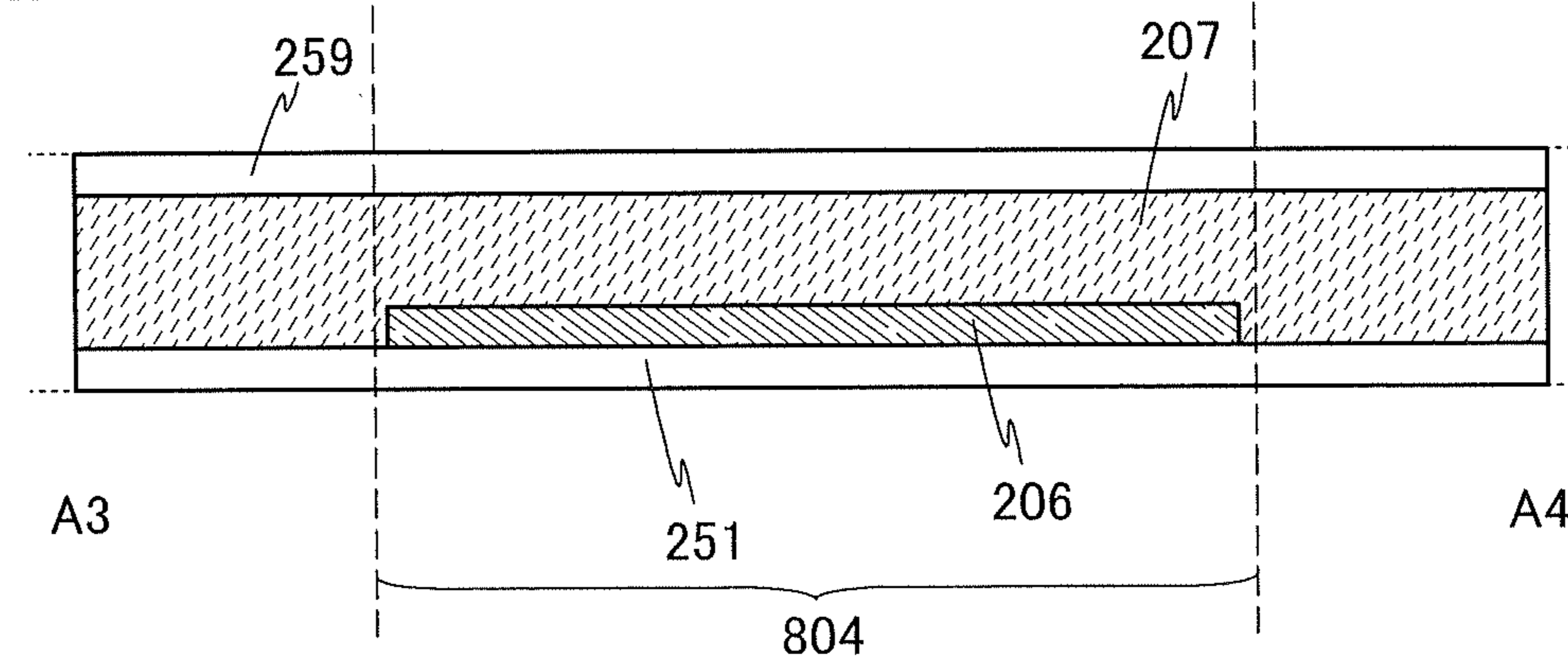


FIG. 3A

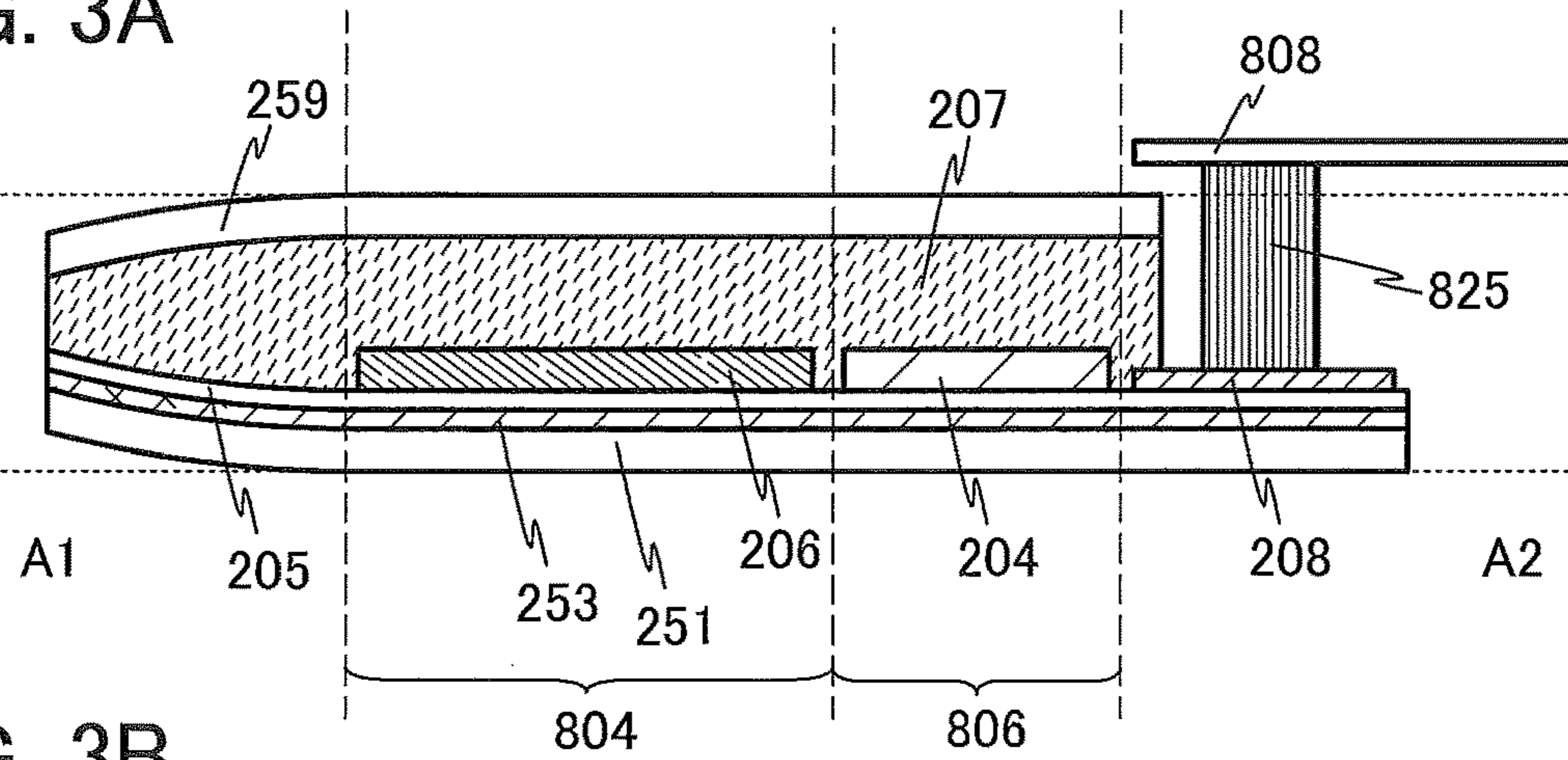


FIG. 3B

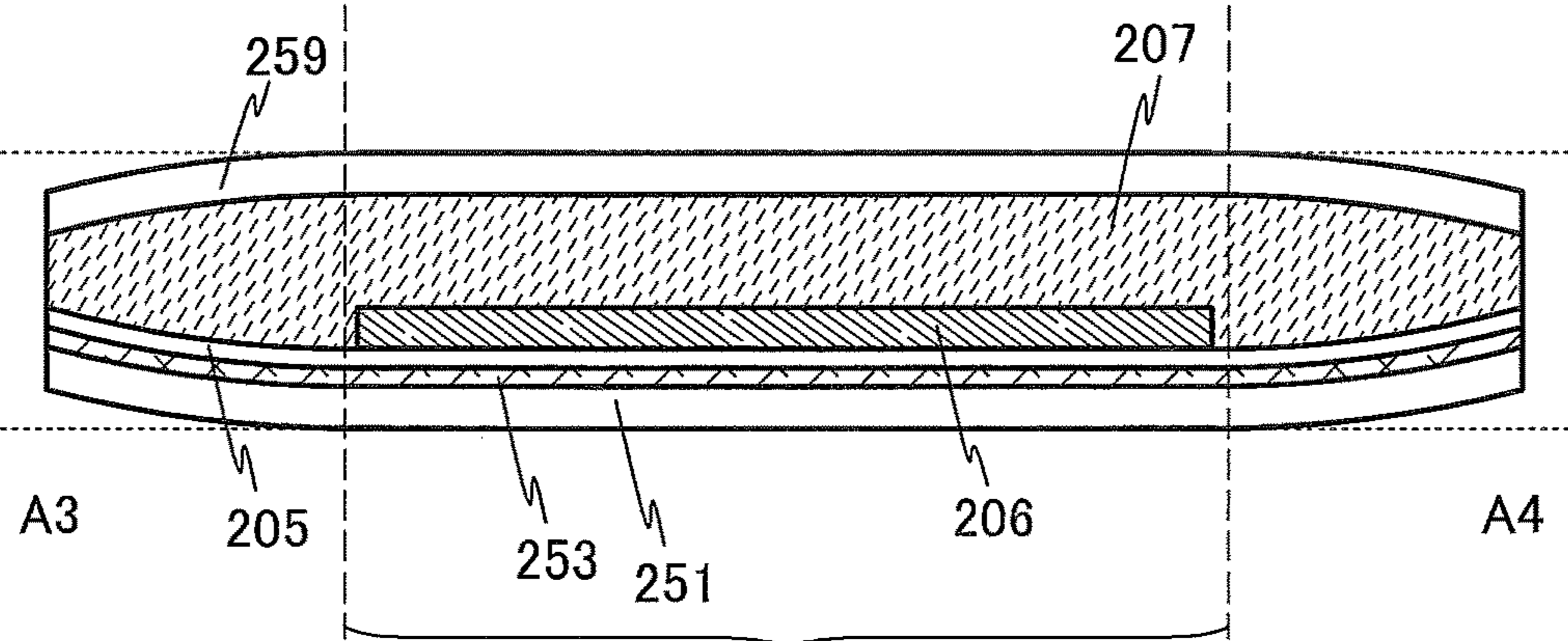


FIG. 3C

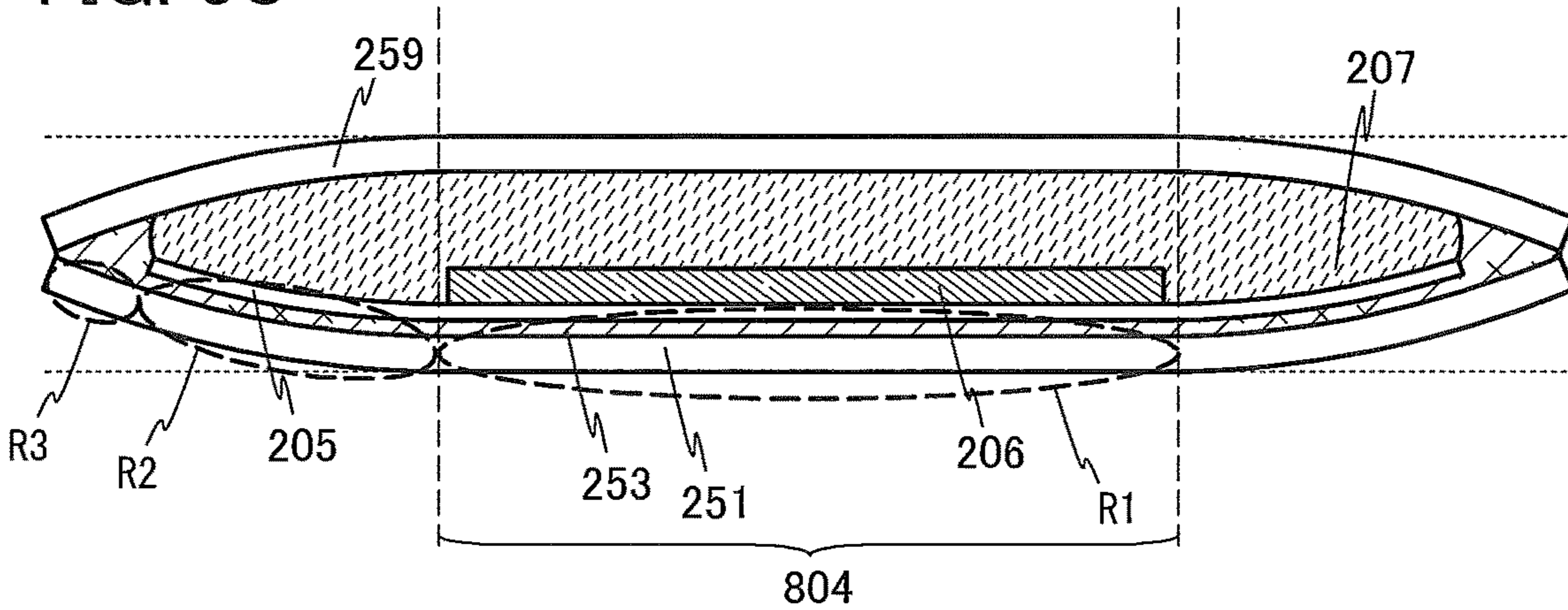


FIG. 3D

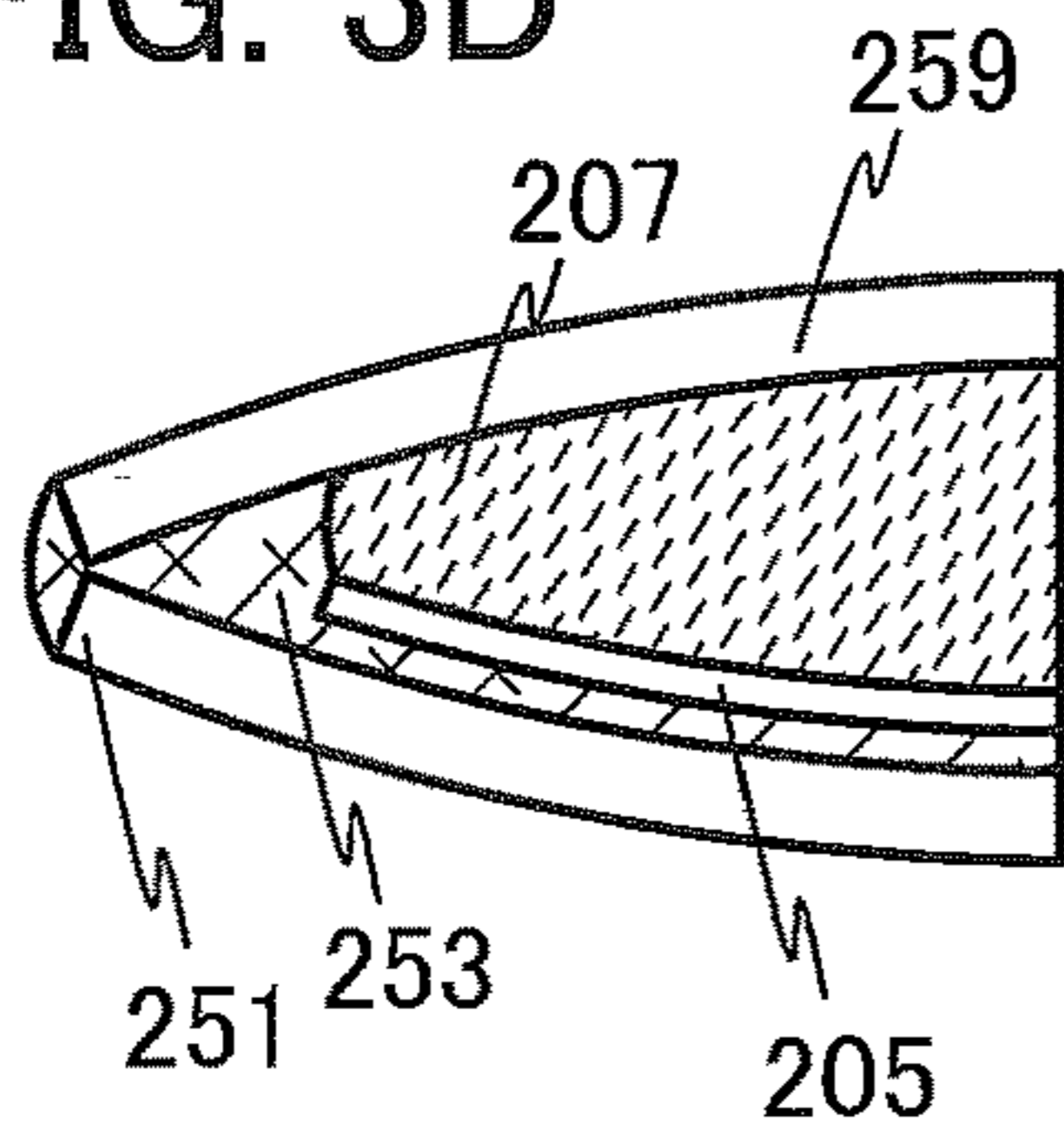


FIG. 3E

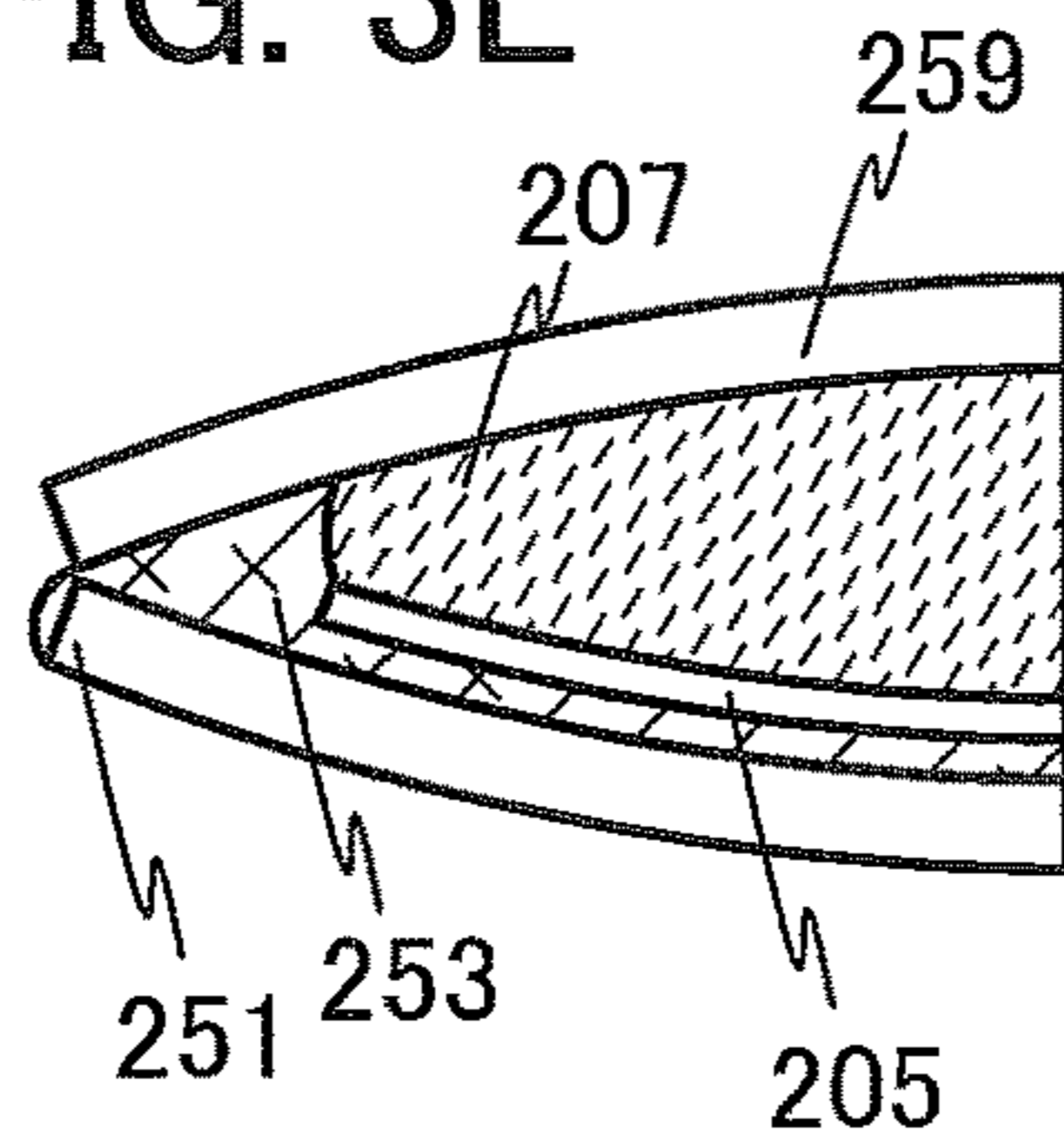


FIG. 3F

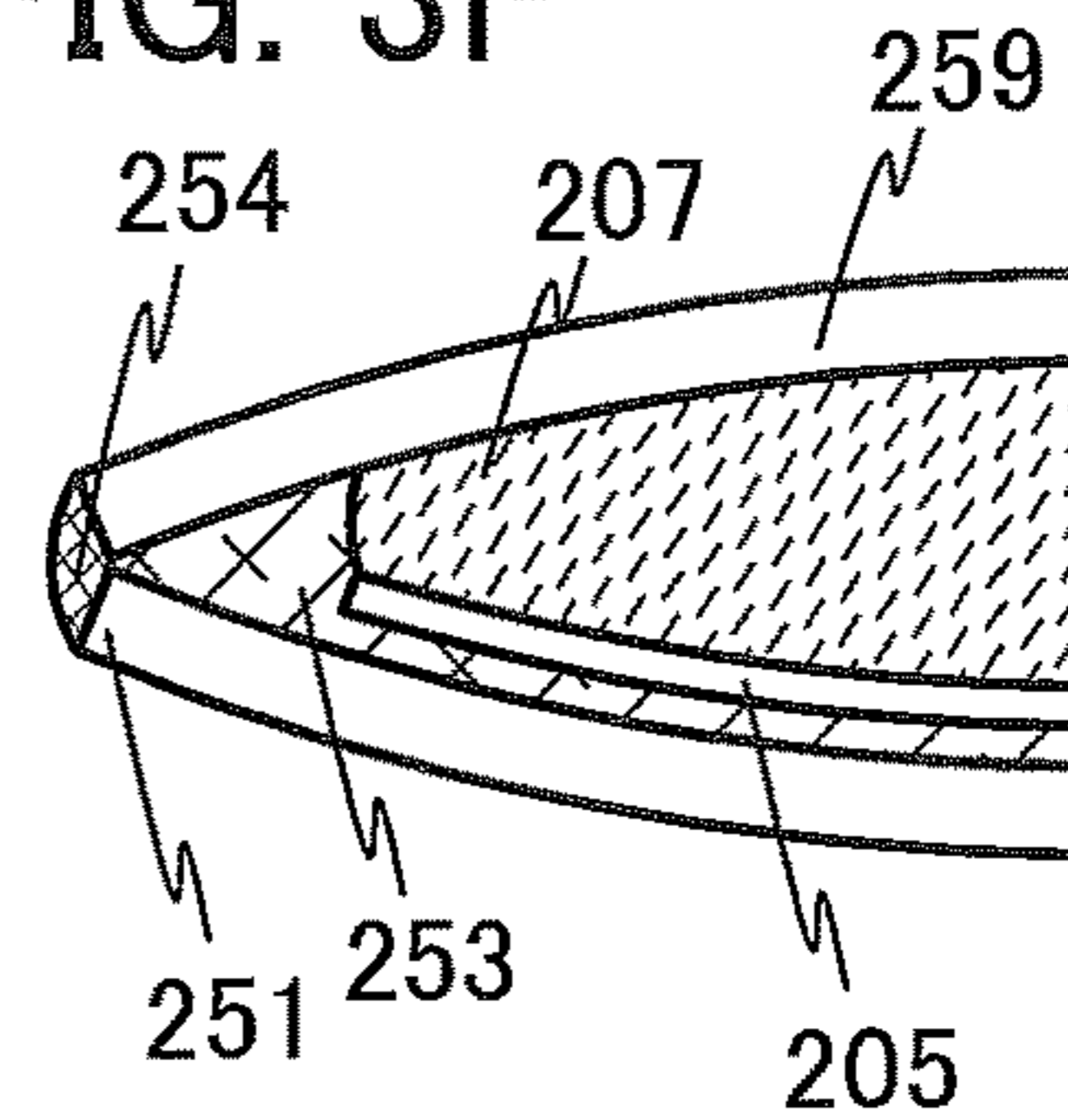


FIG. 4A

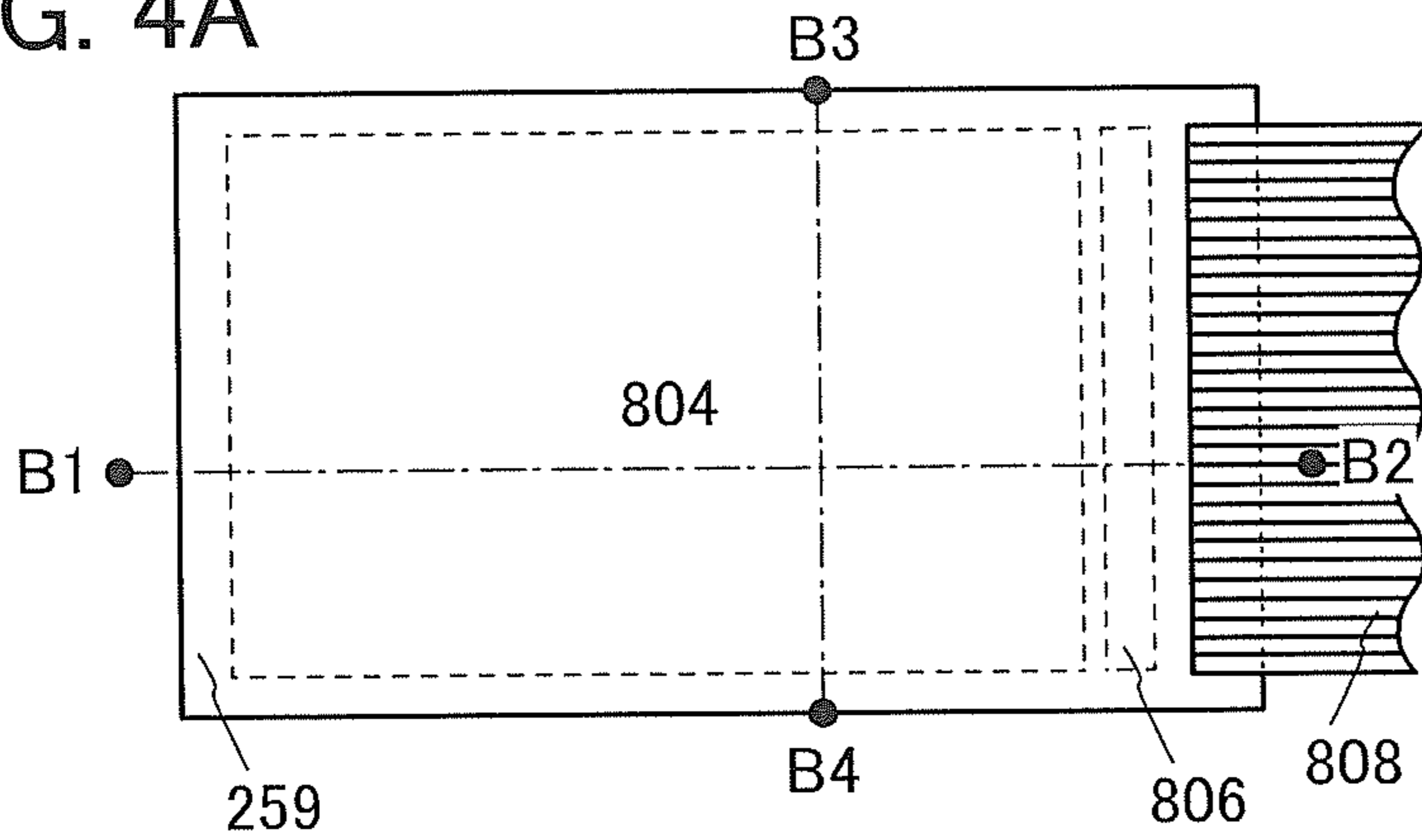


FIG. 4B

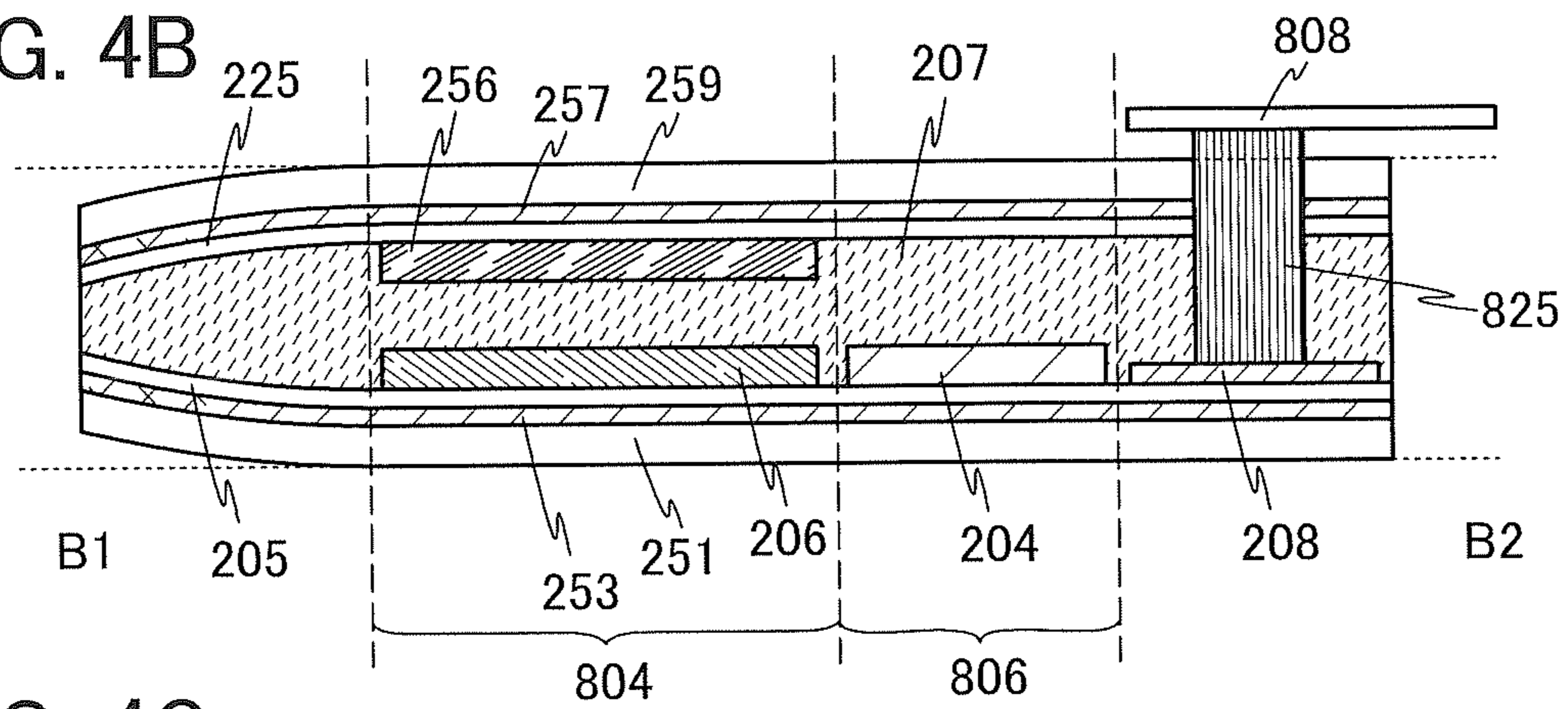


FIG. 4C

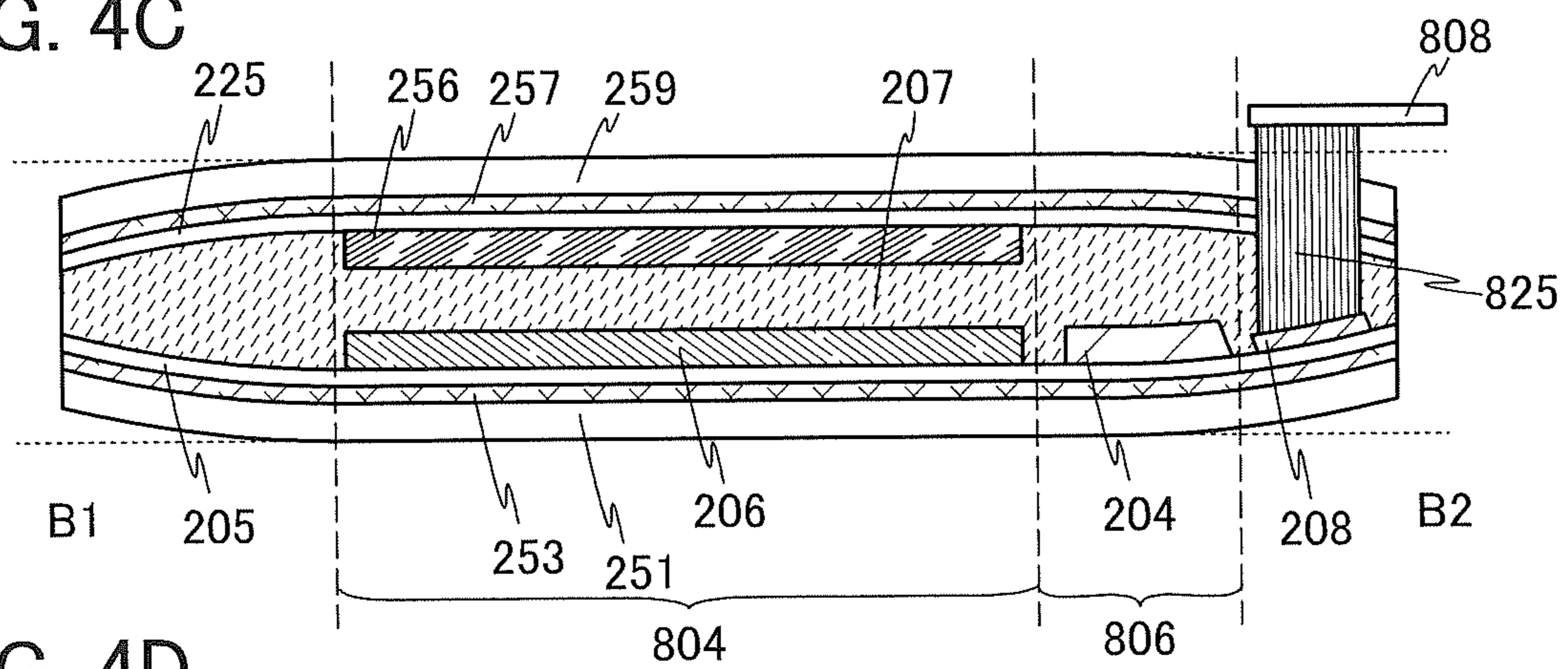


FIG. 4D

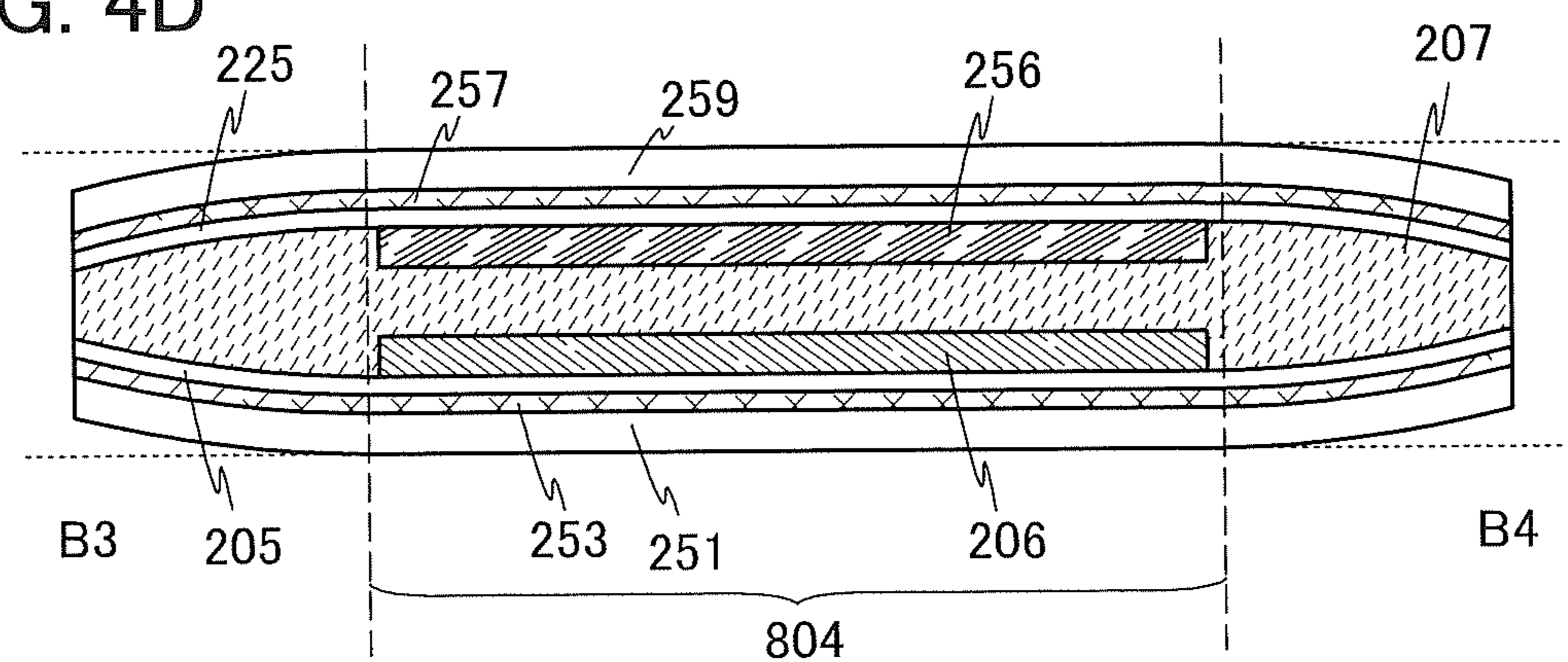


FIG. 5A

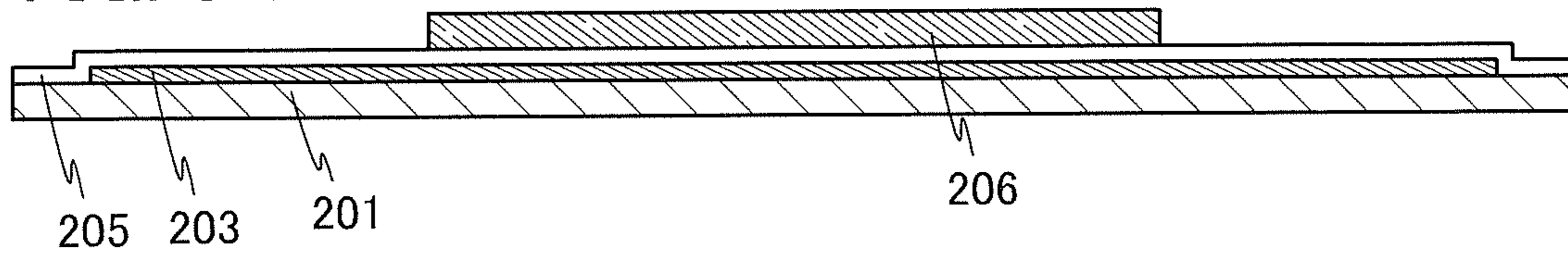


FIG. 5B

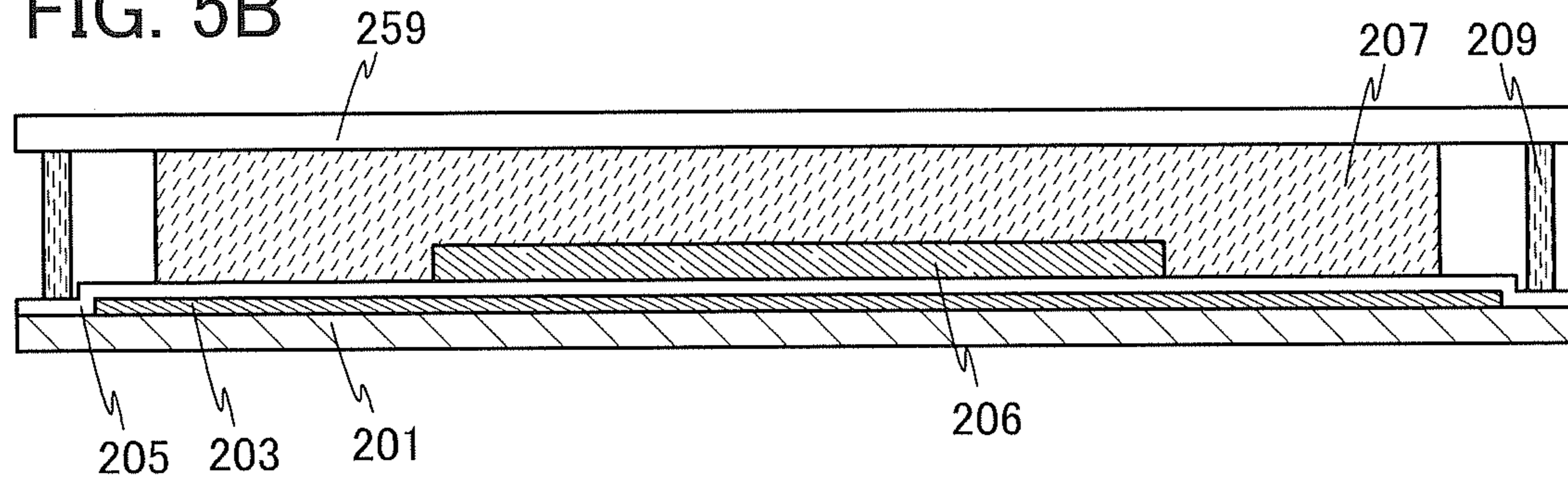


FIG. 5C

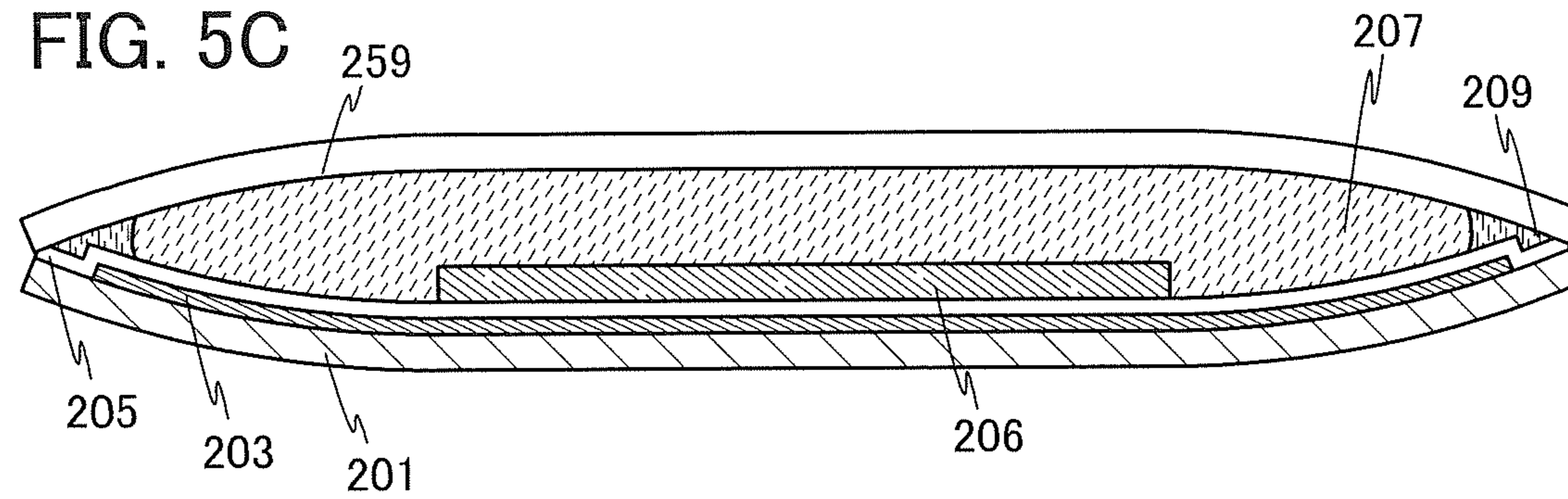


FIG. 5D

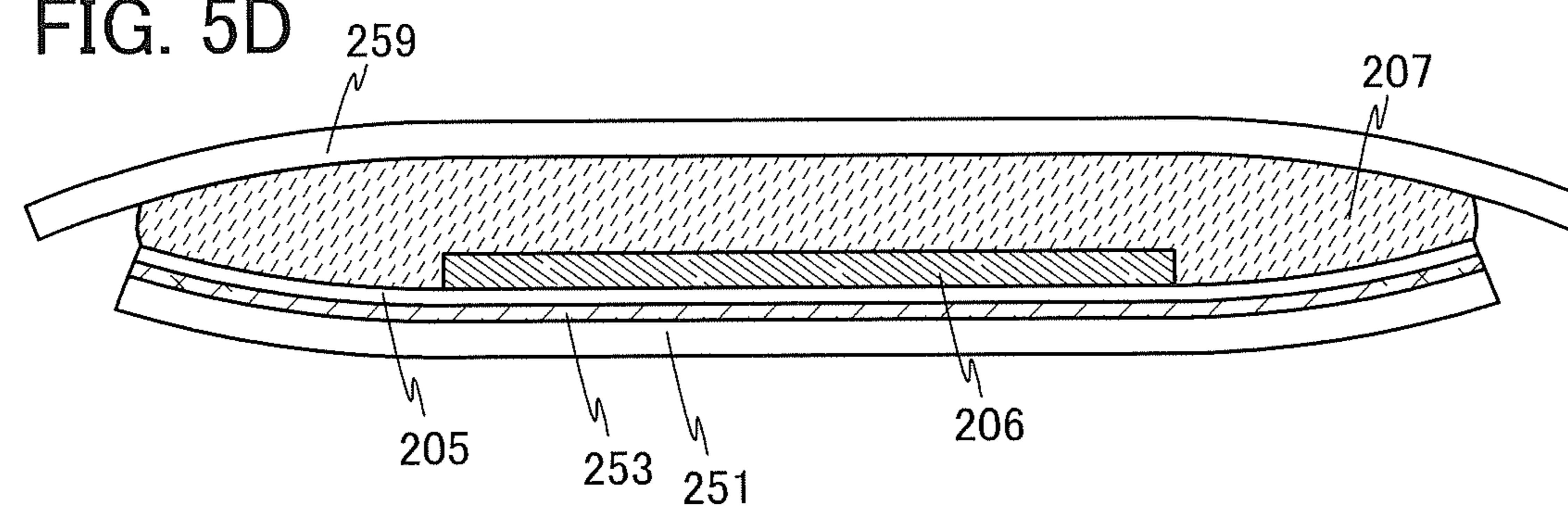


FIG. 5E

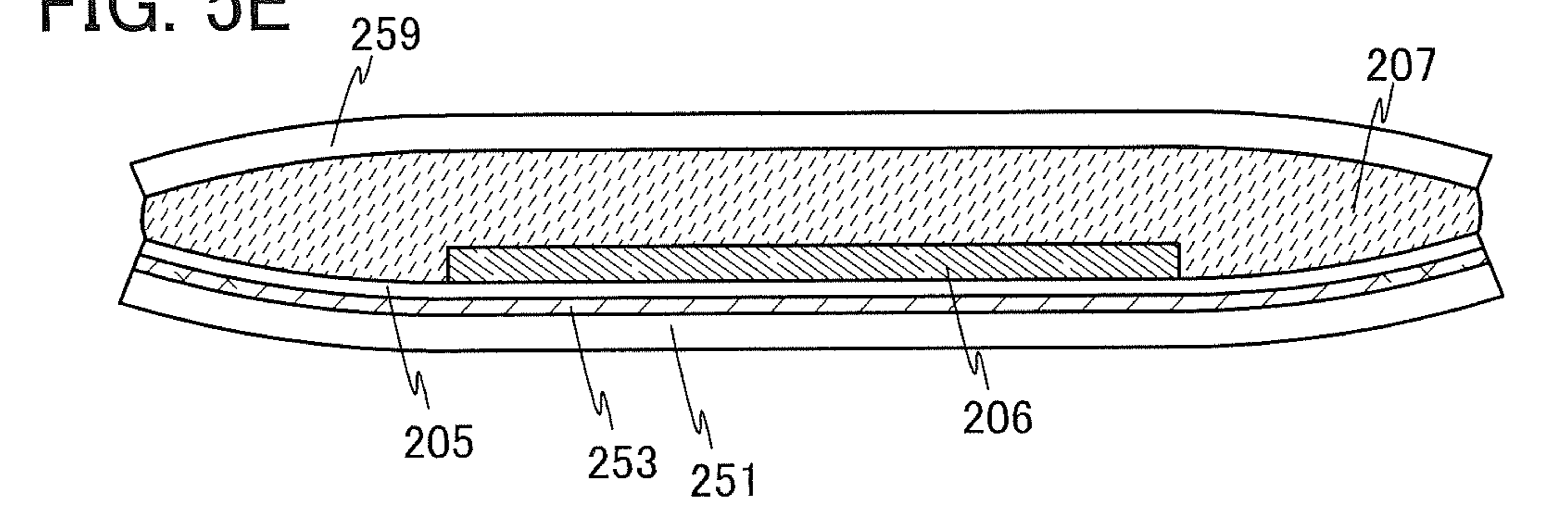




FIG. 6A

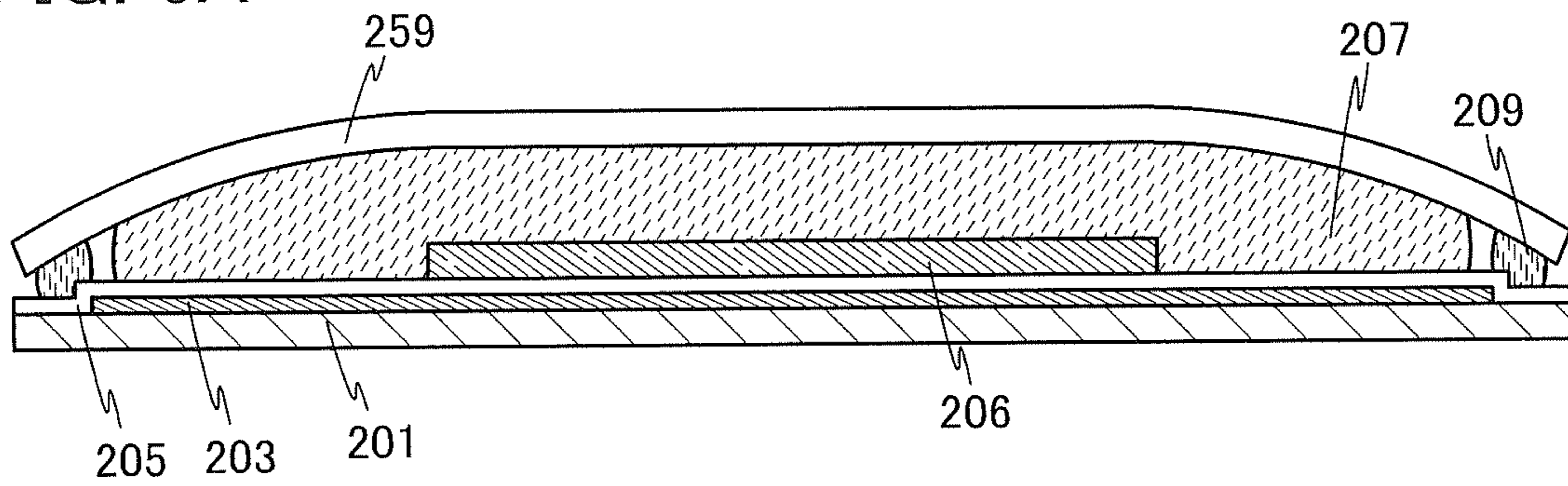


FIG. 6B

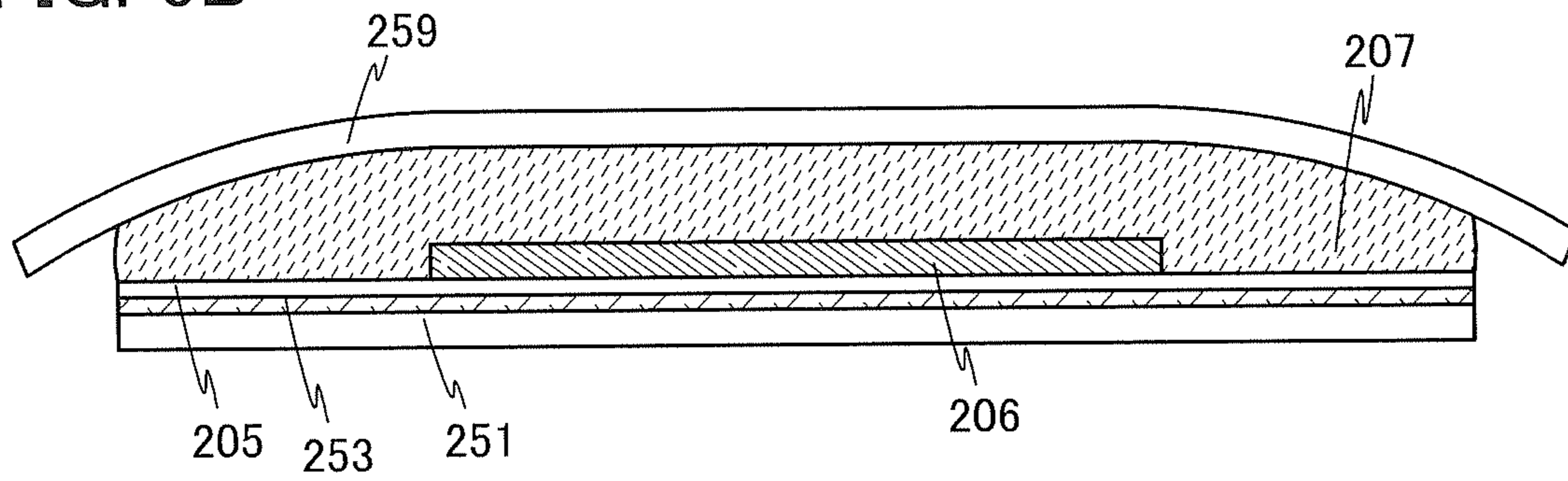


FIG. 7A

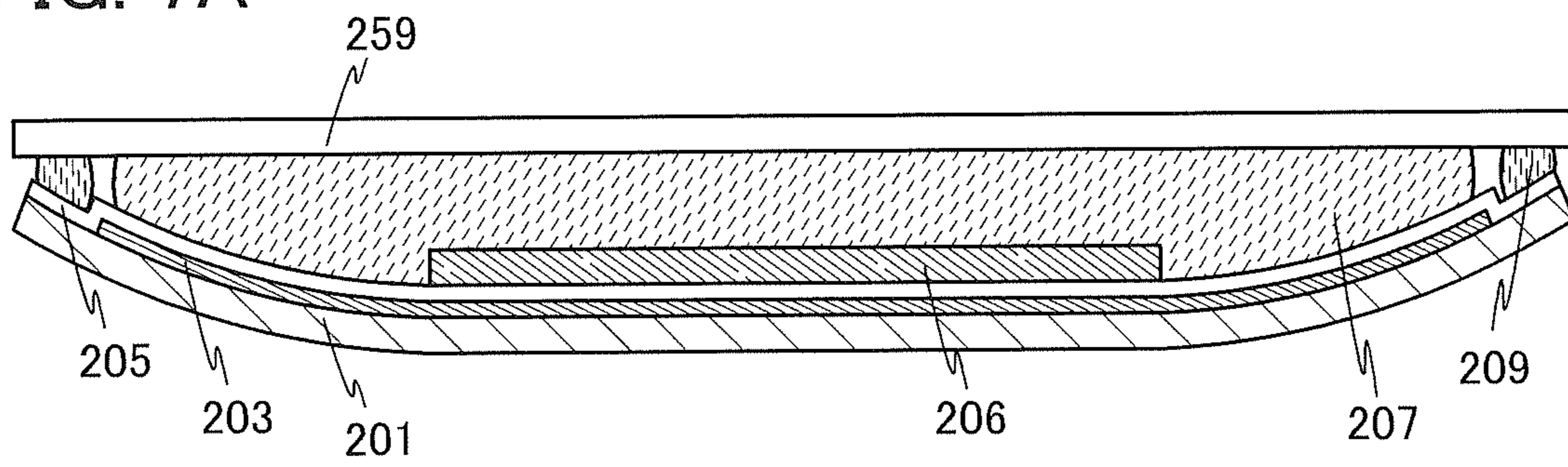


FIG. 7B

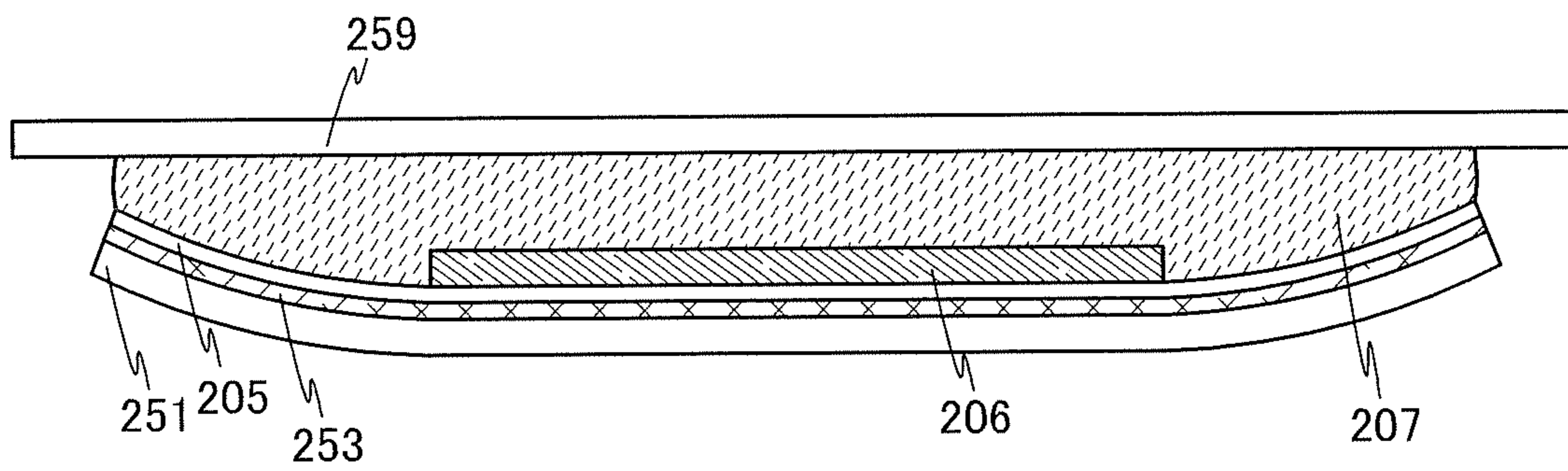


FIG. 8A

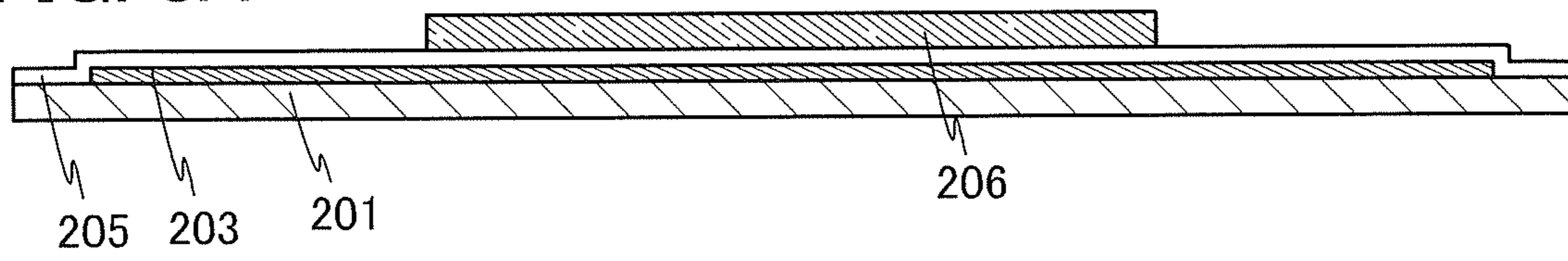


FIG. 8B

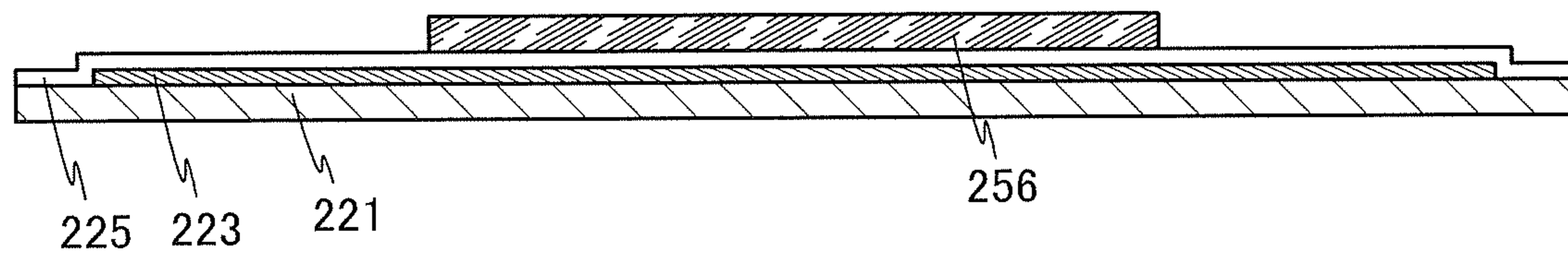


FIG. 8C

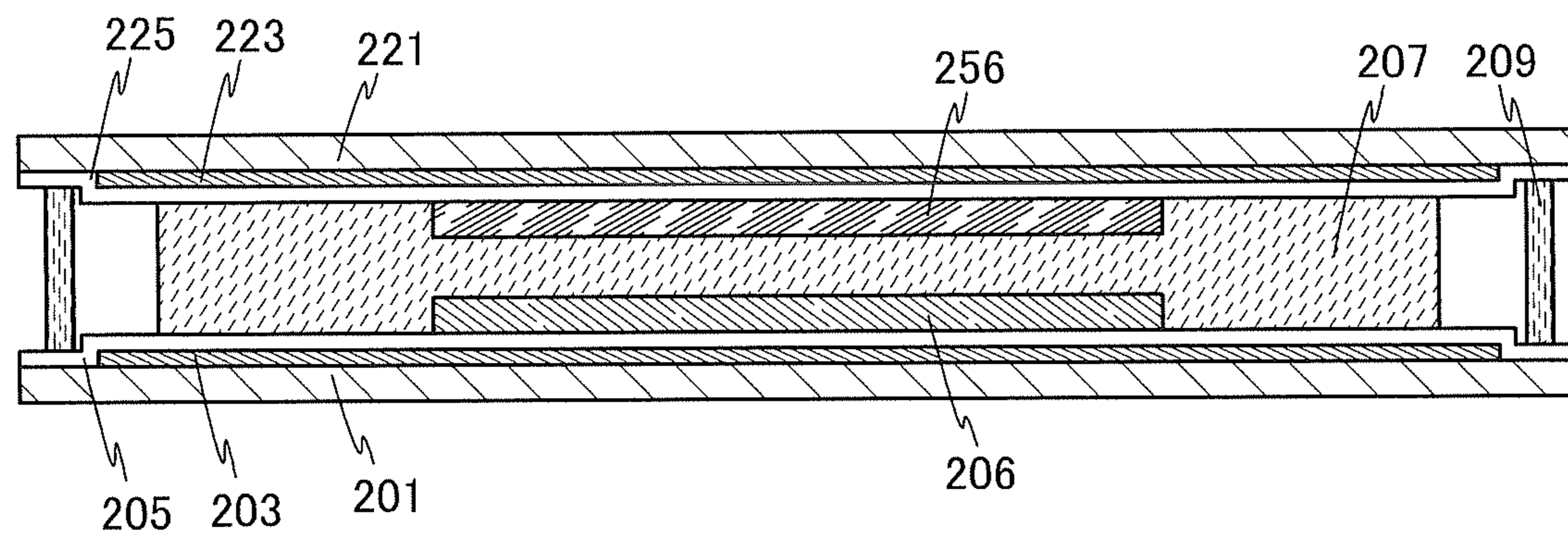


FIG. 8D

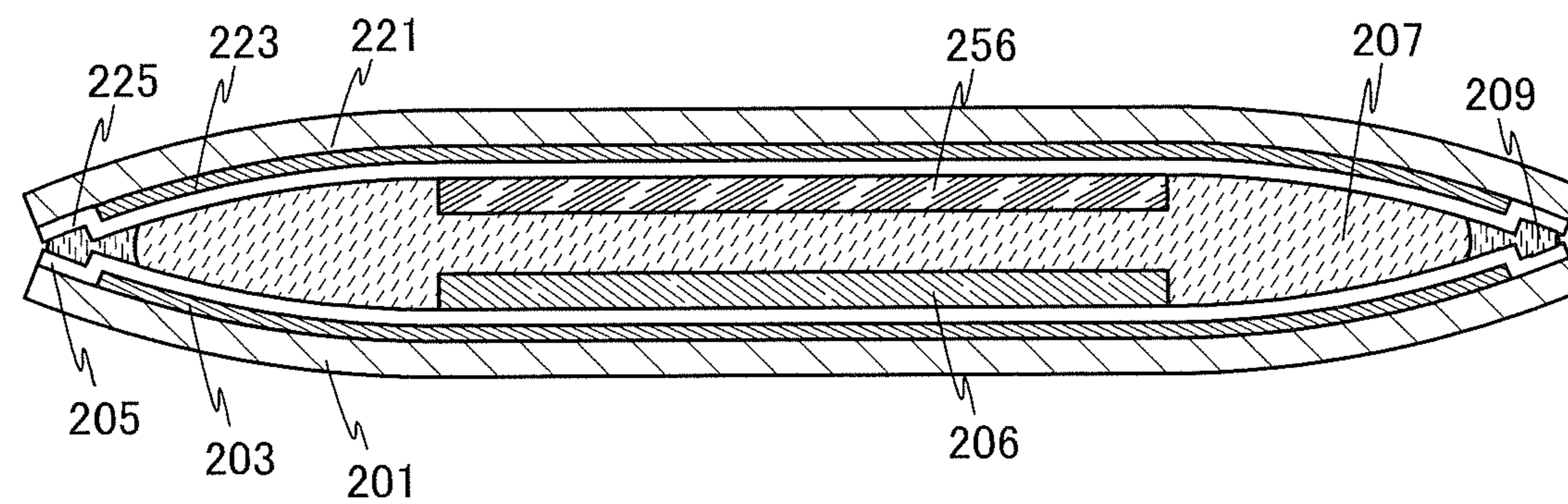


FIG. 9A

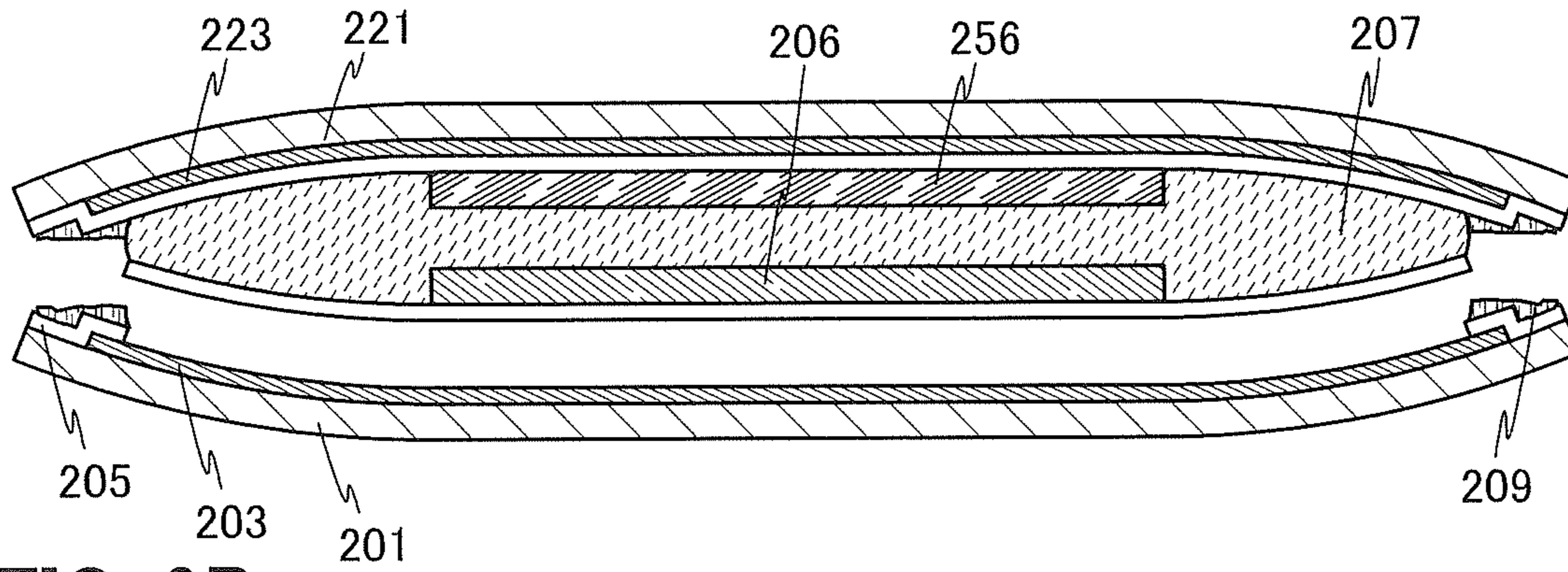


FIG. 9B

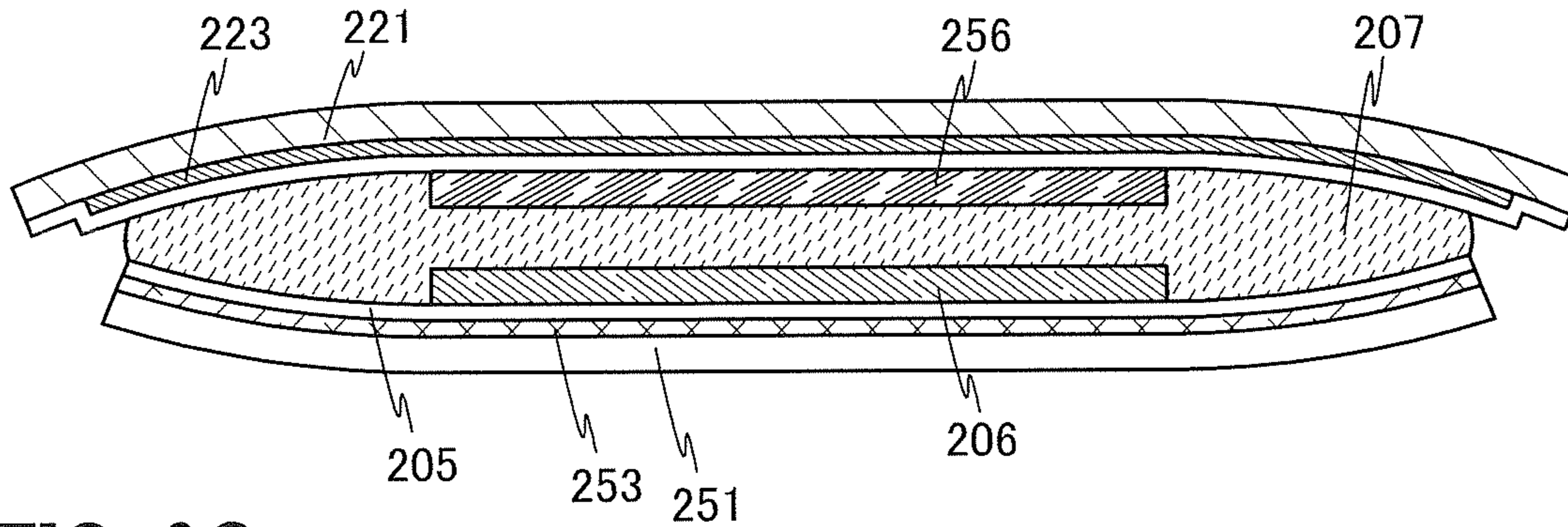


FIG. 9C

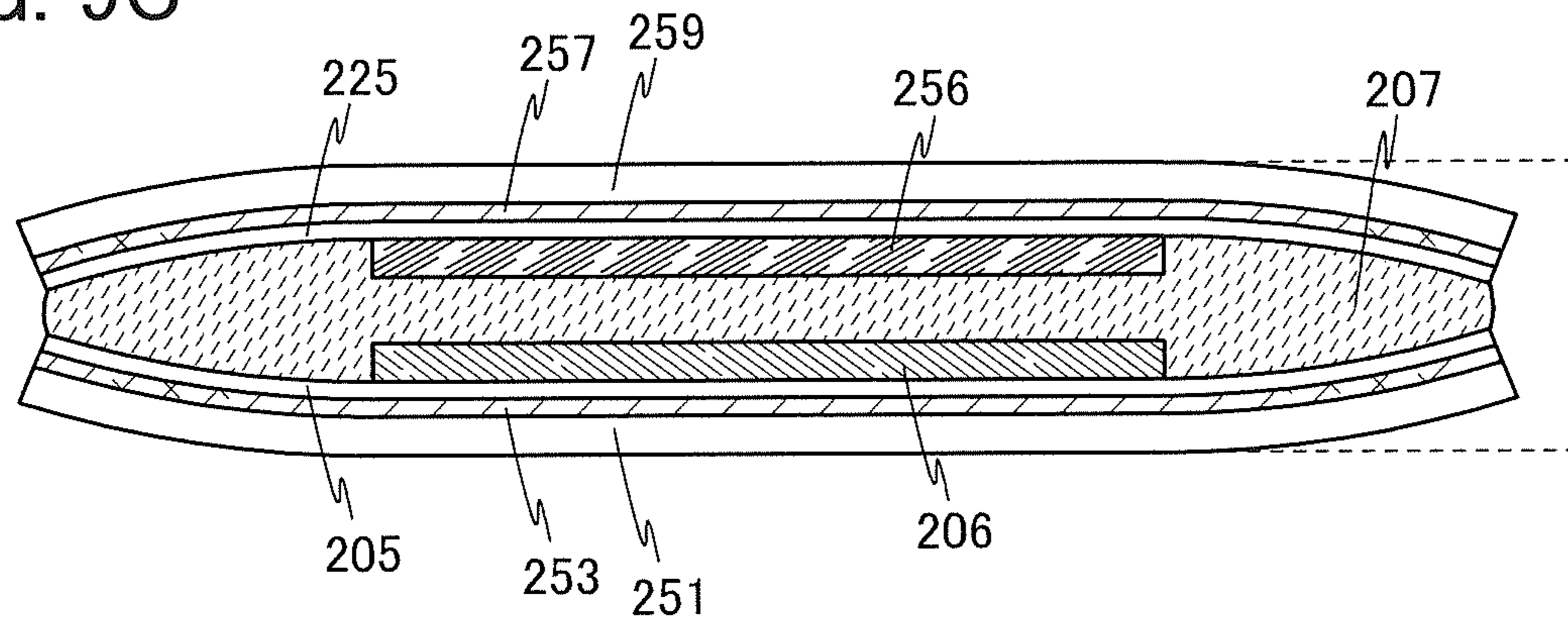


FIG. 9D

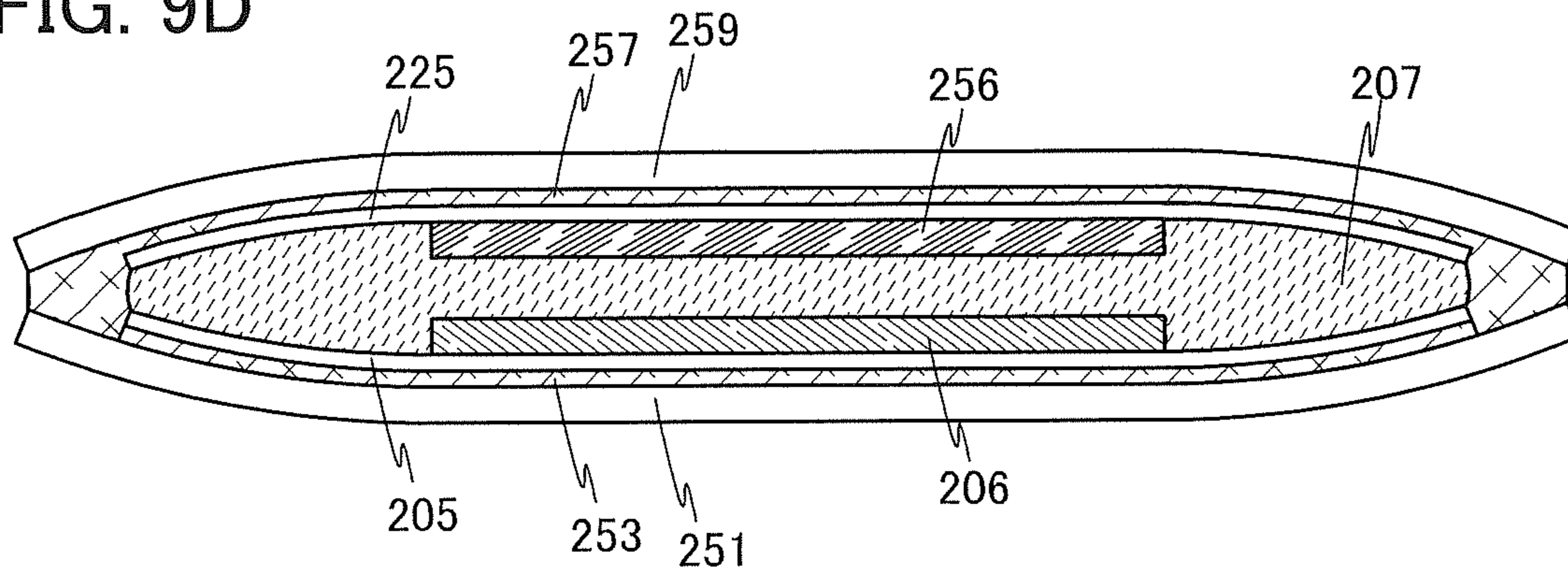


FIG. 10A

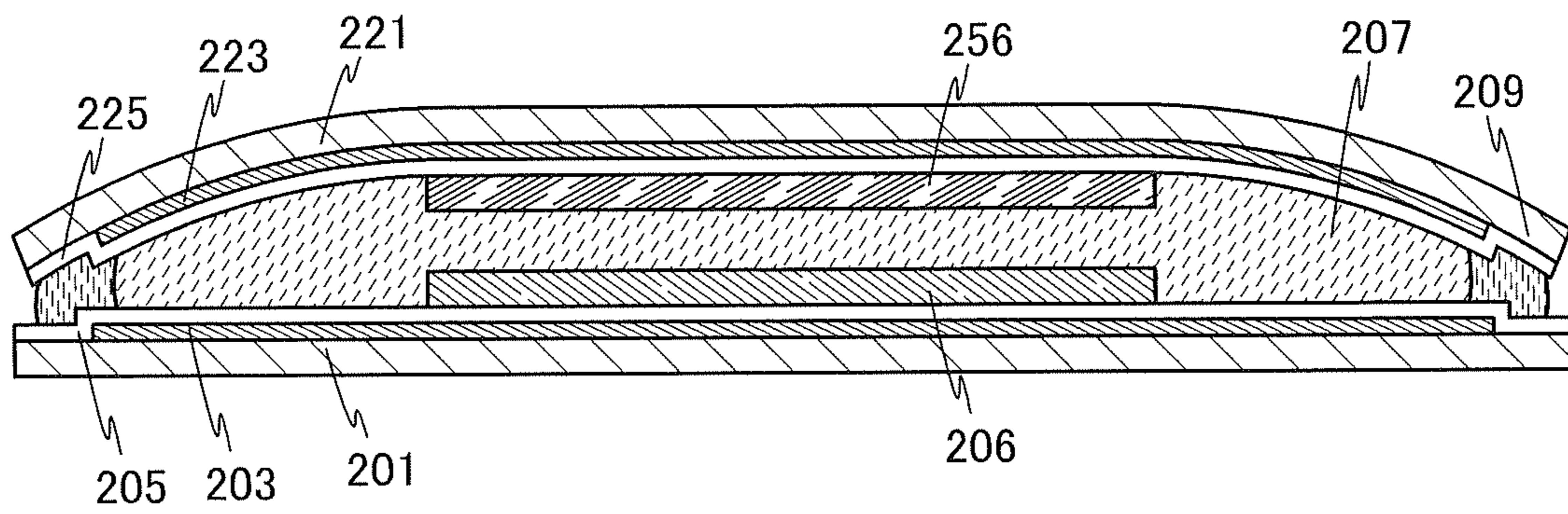


FIG. 10B

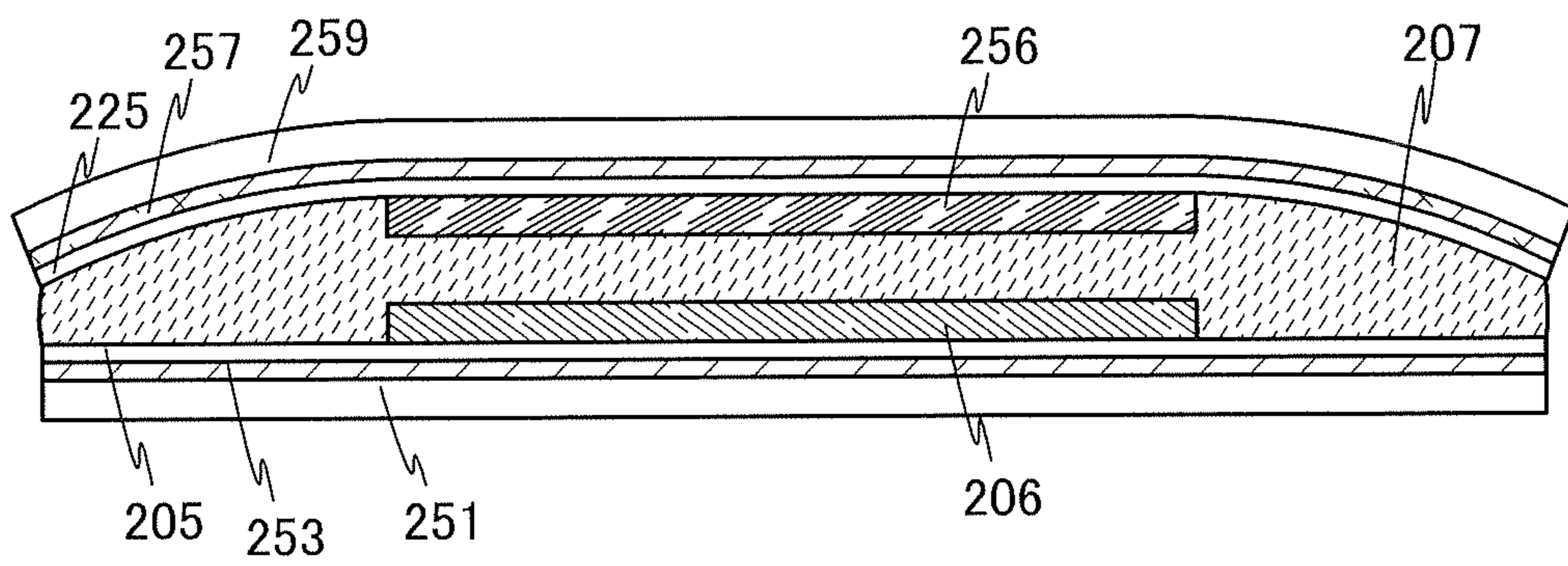


FIG. 11A

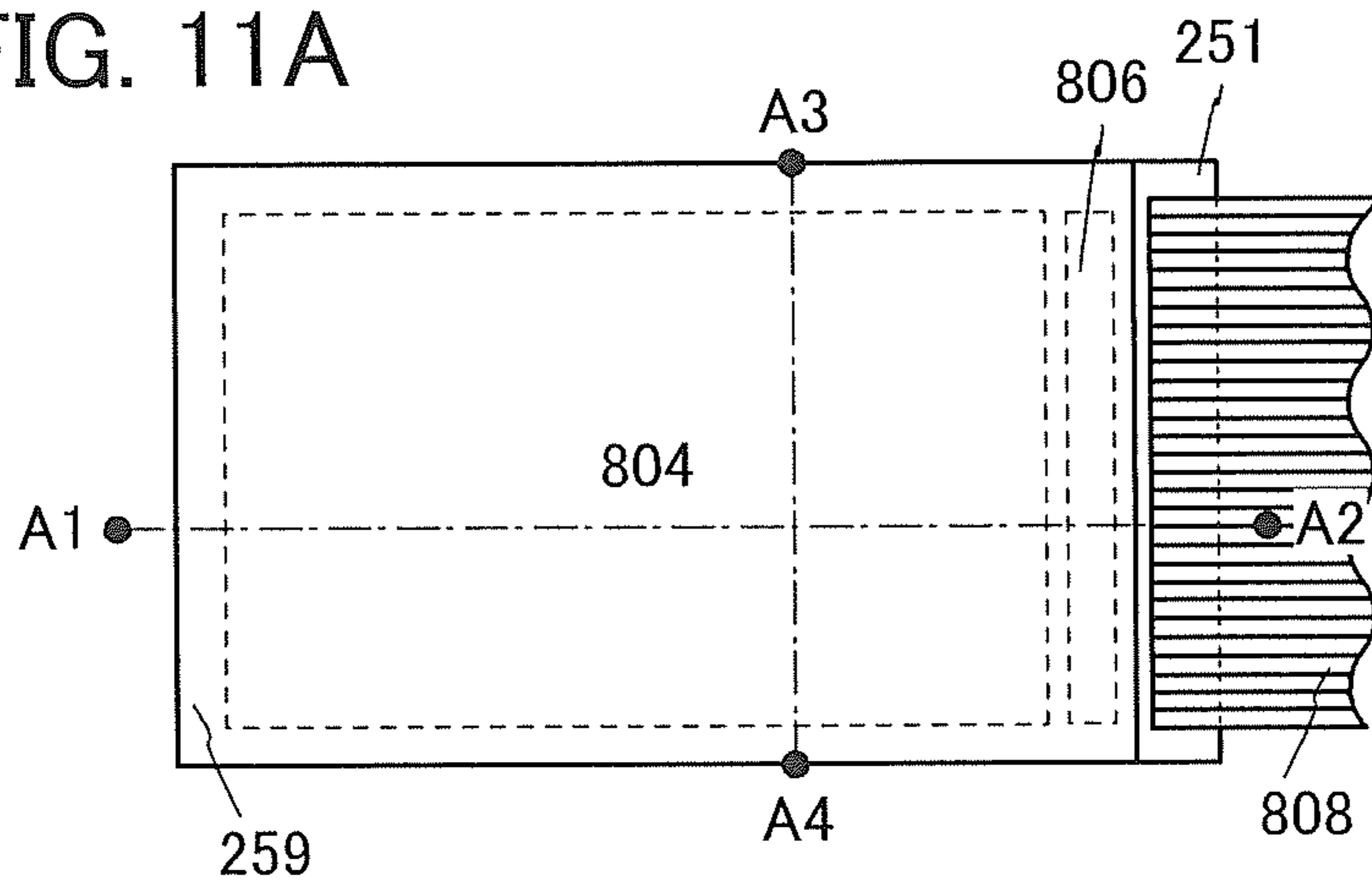


FIG. 11B

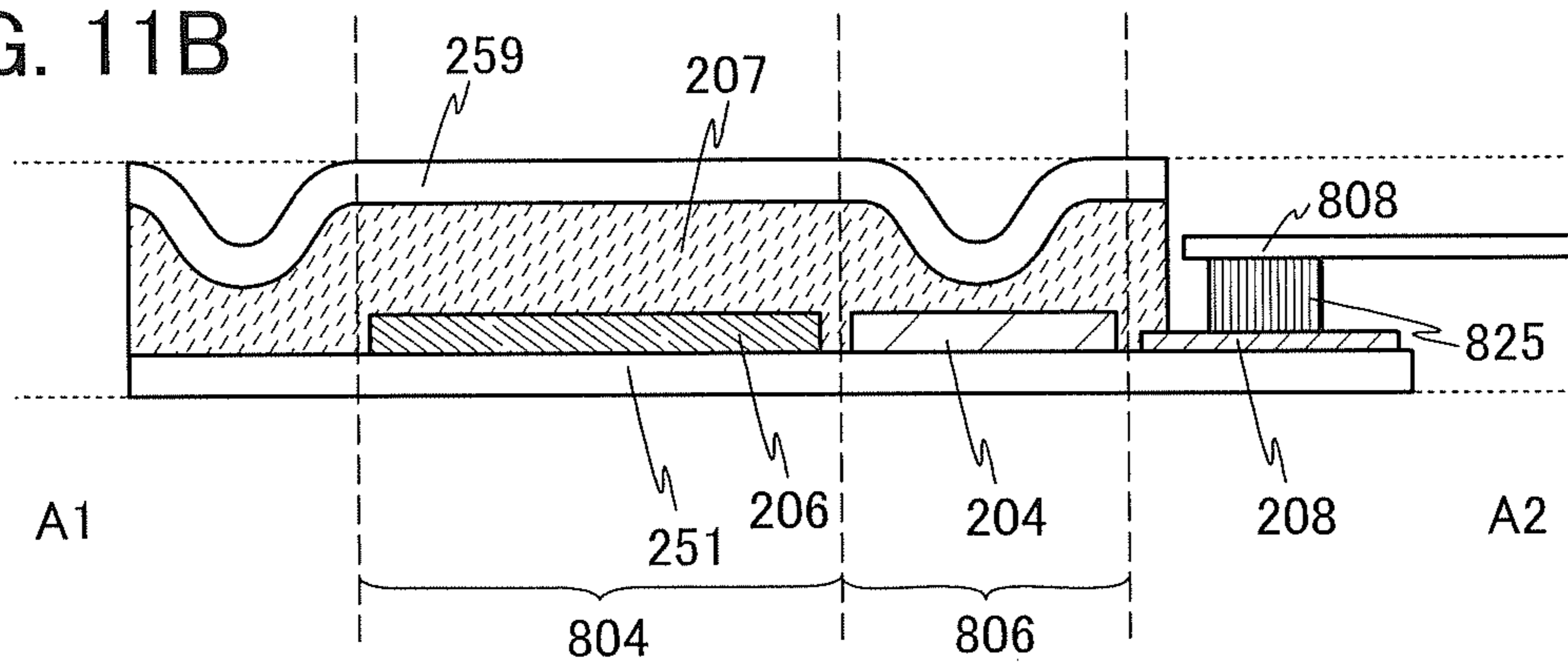


FIG. 11C

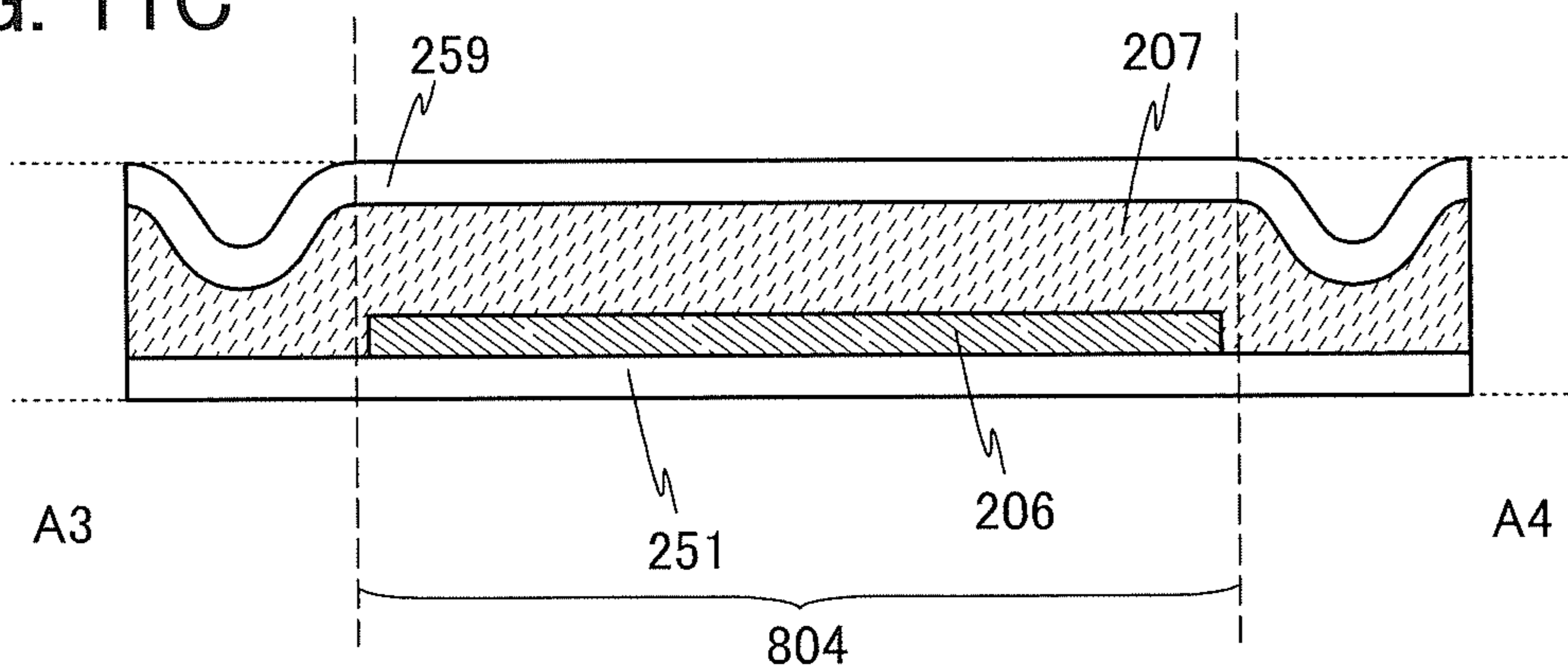


FIG. 12A

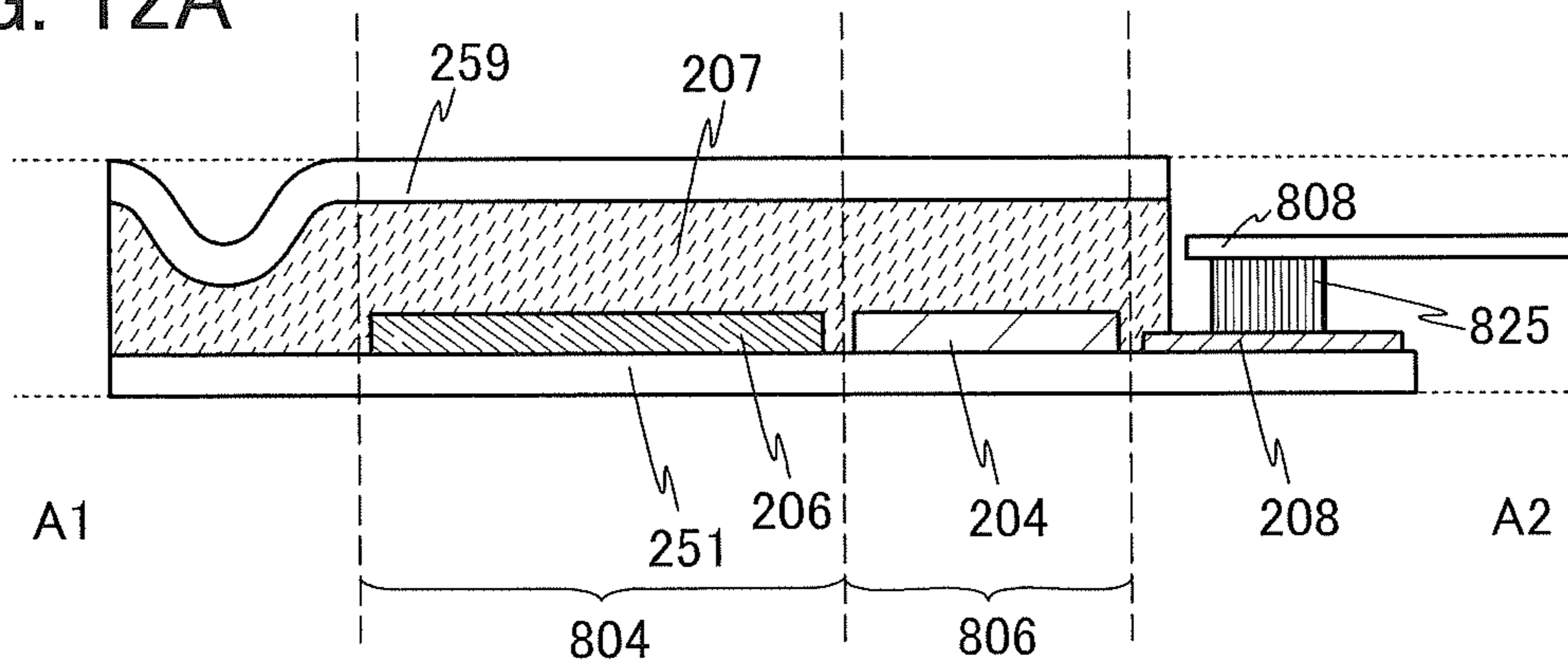


FIG. 12B

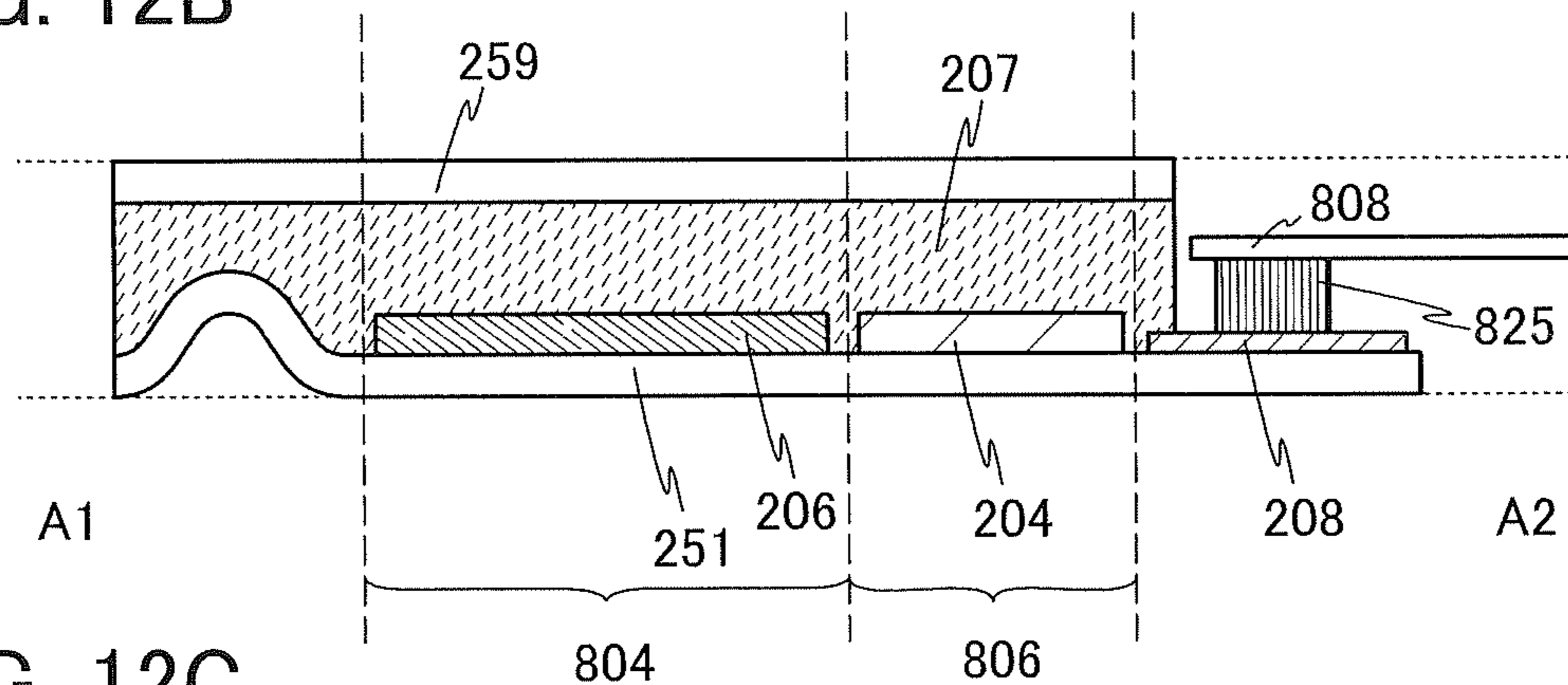


FIG. 12C

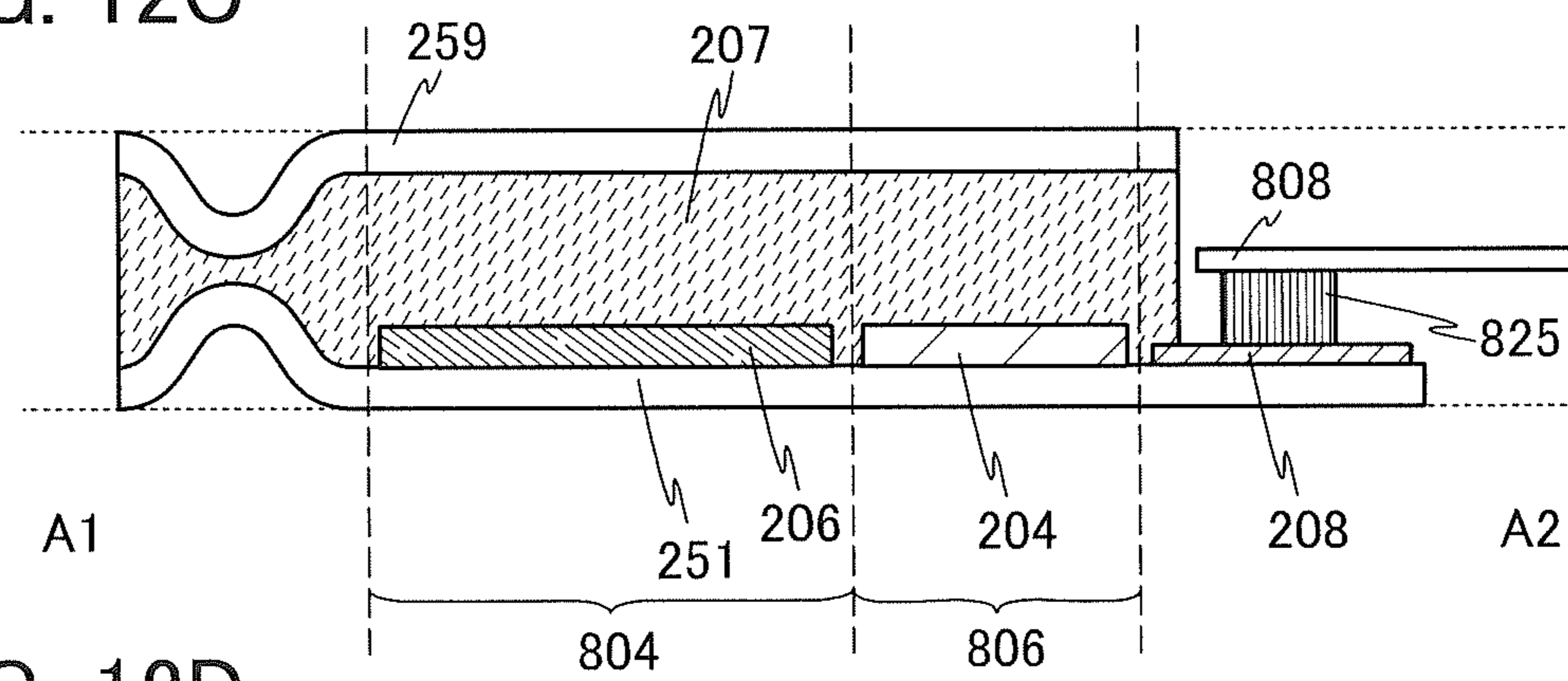


FIG. 12D

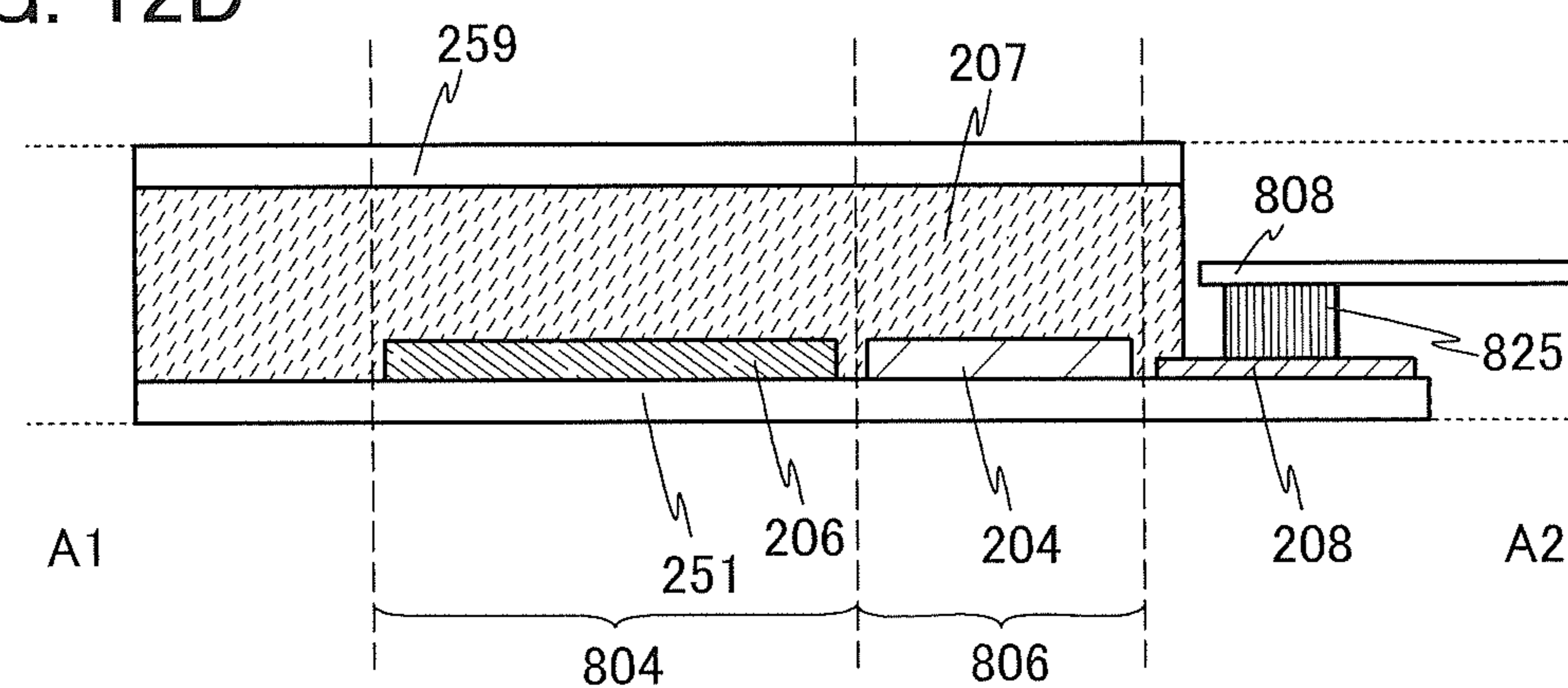


FIG. 13A

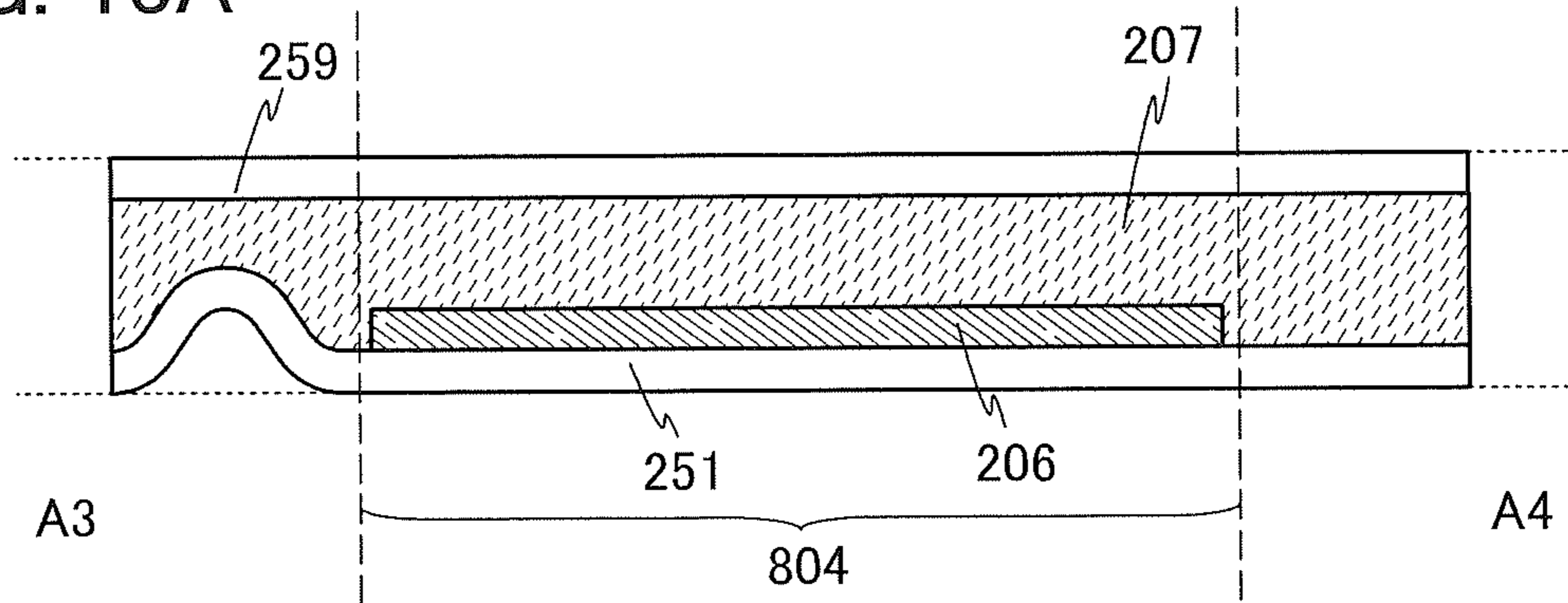


FIG. 13B

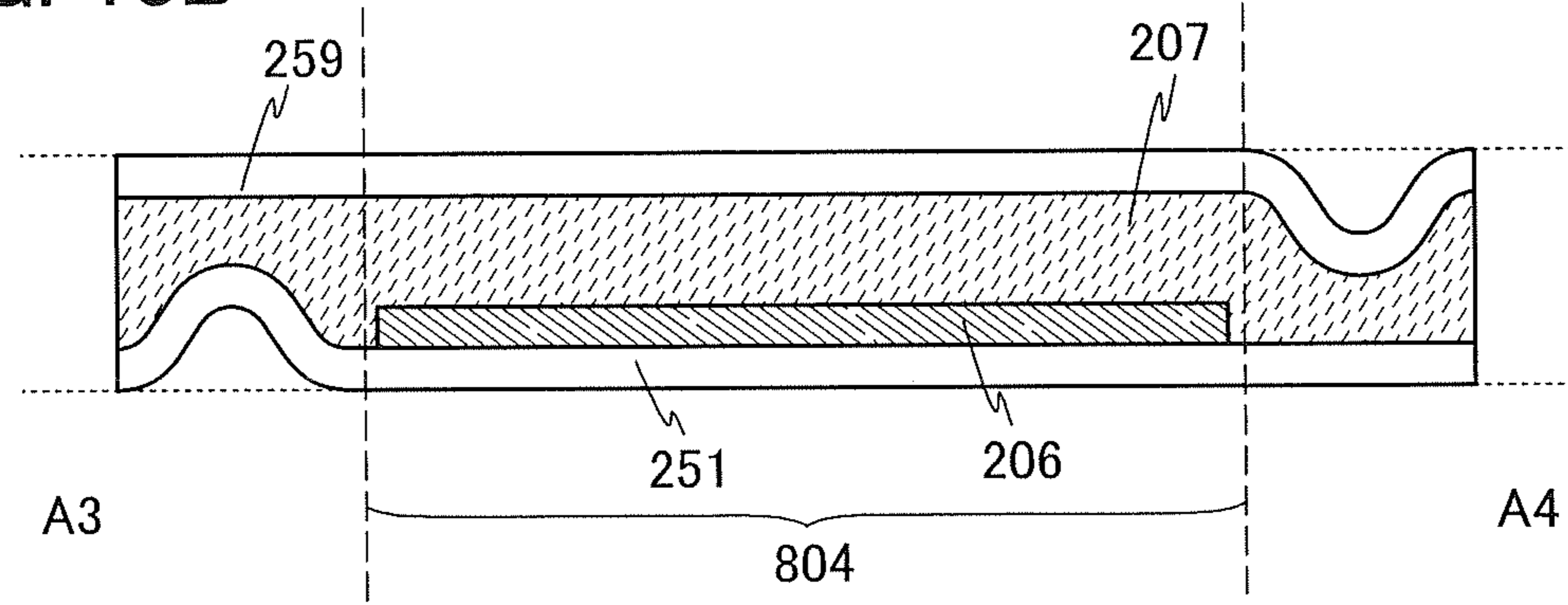


FIG. 13C

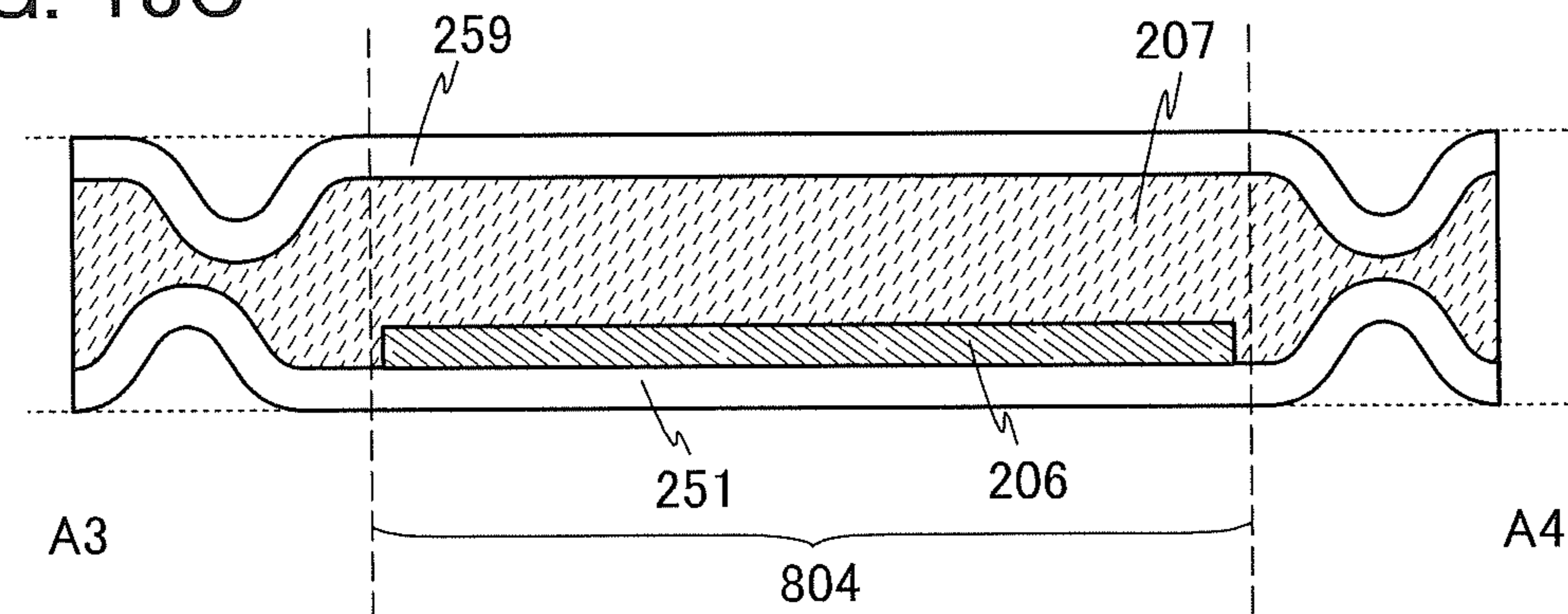


FIG. 13D

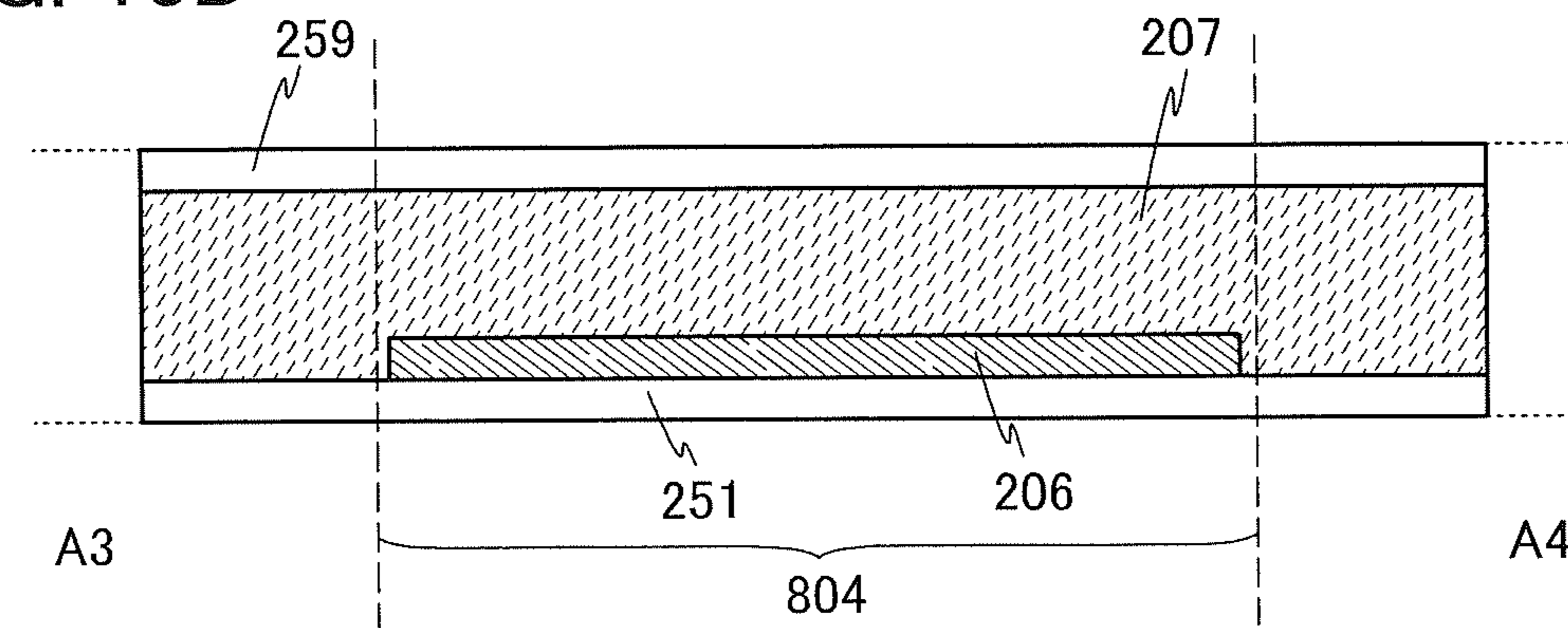




FIG. 14A

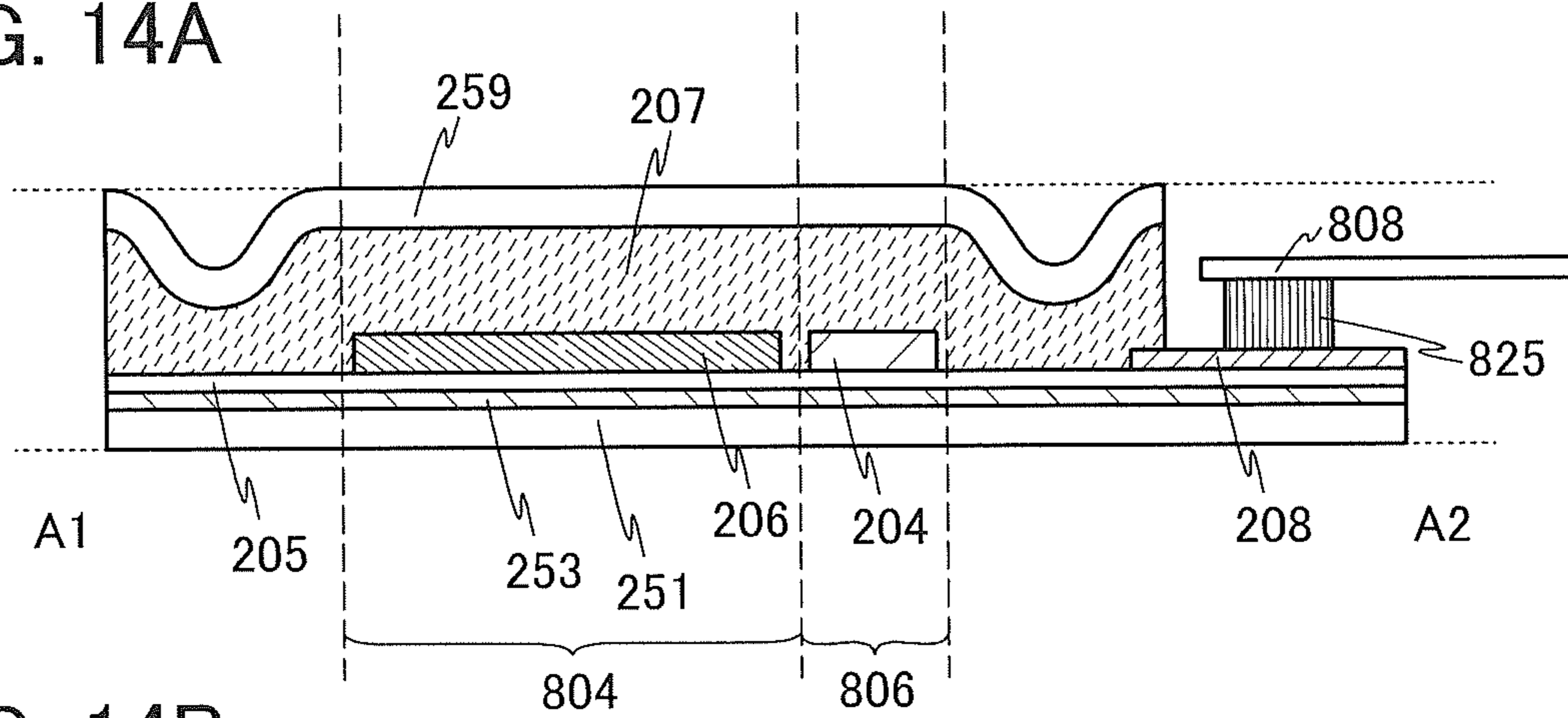


FIG. 14B

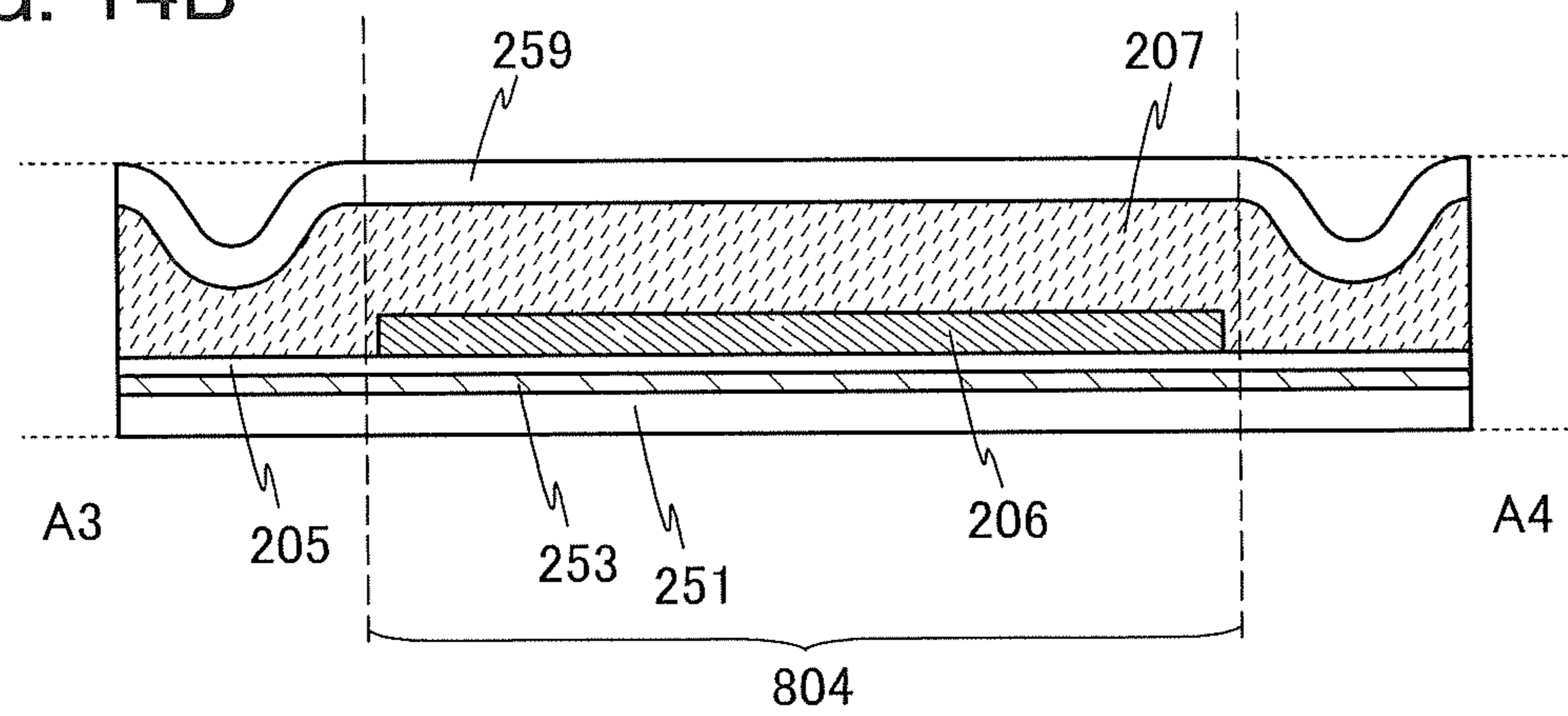


FIG. 15A

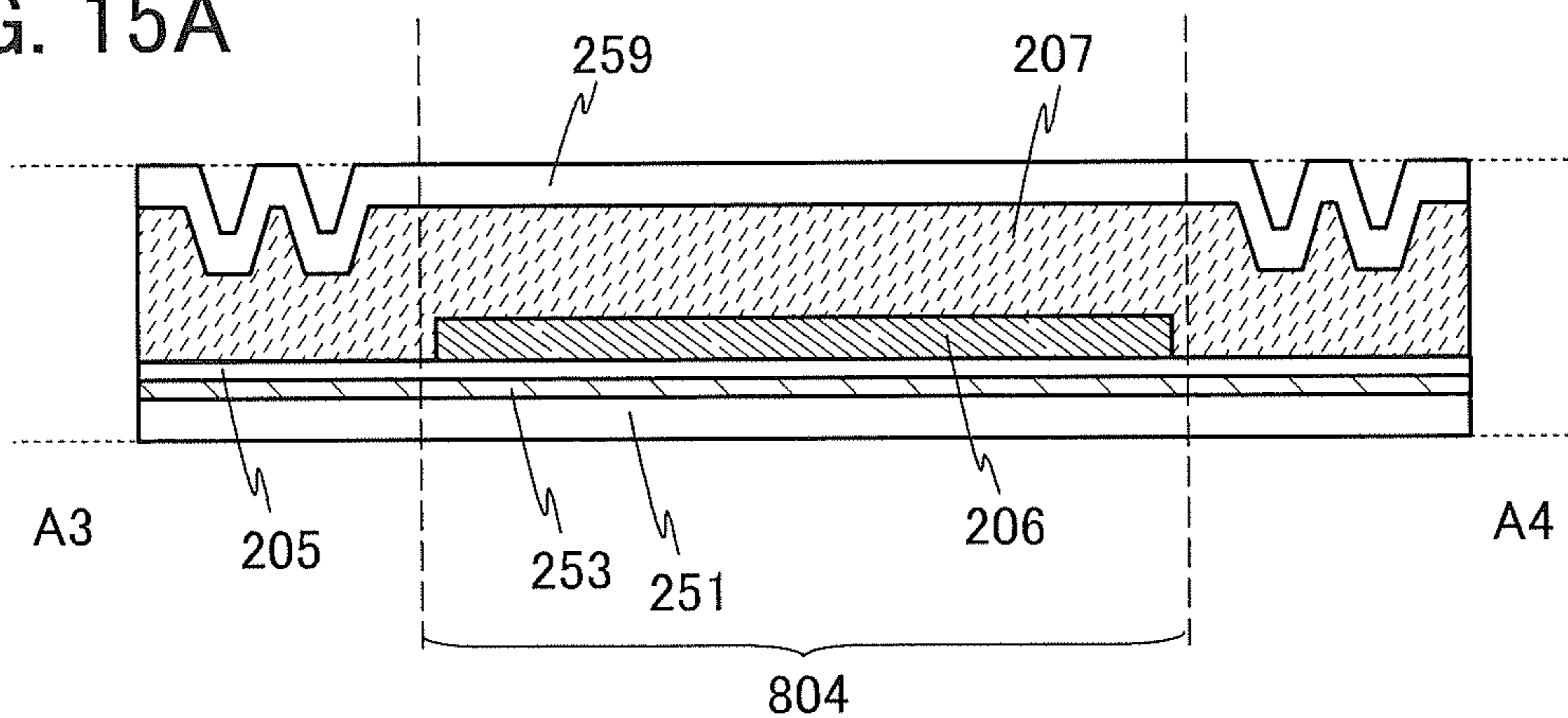


FIG. 15B

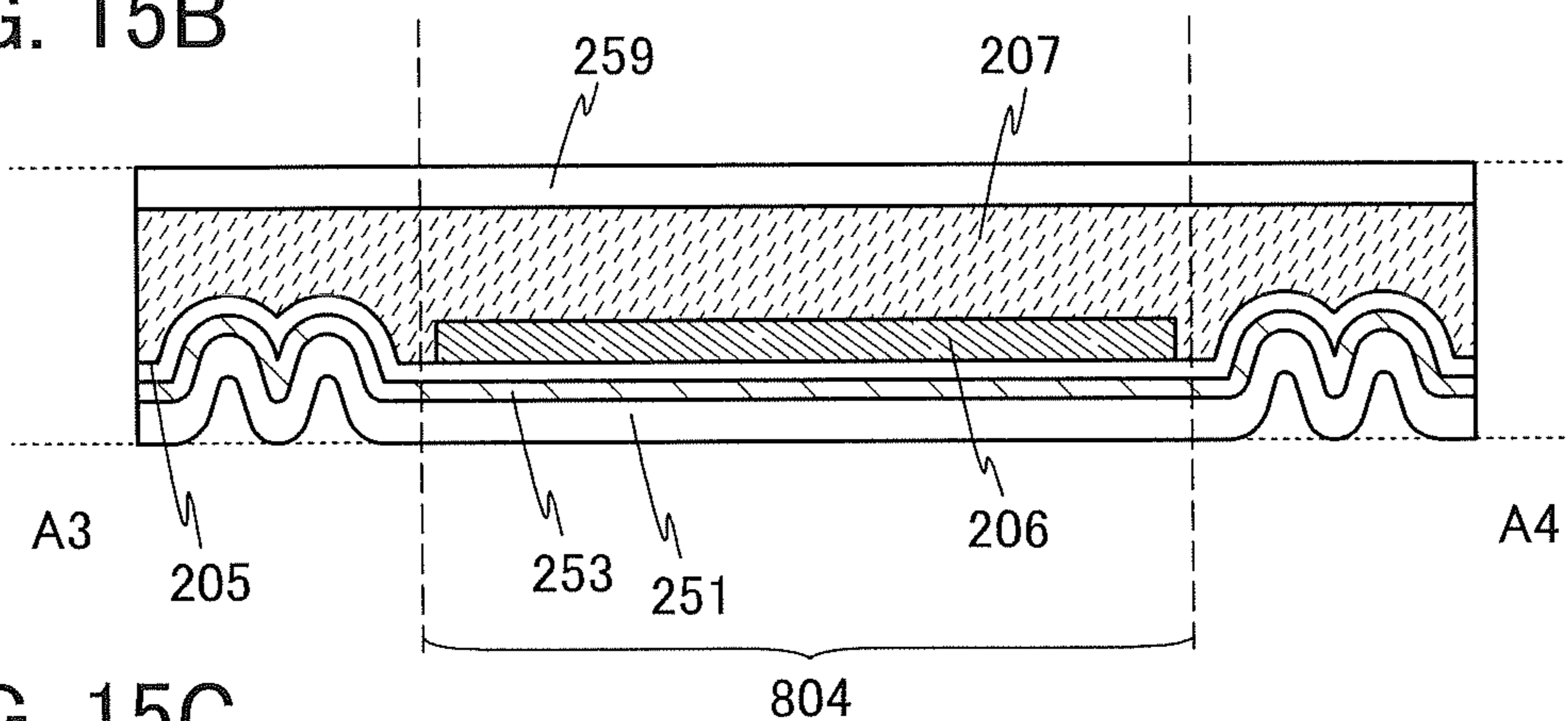


FIG. 15C

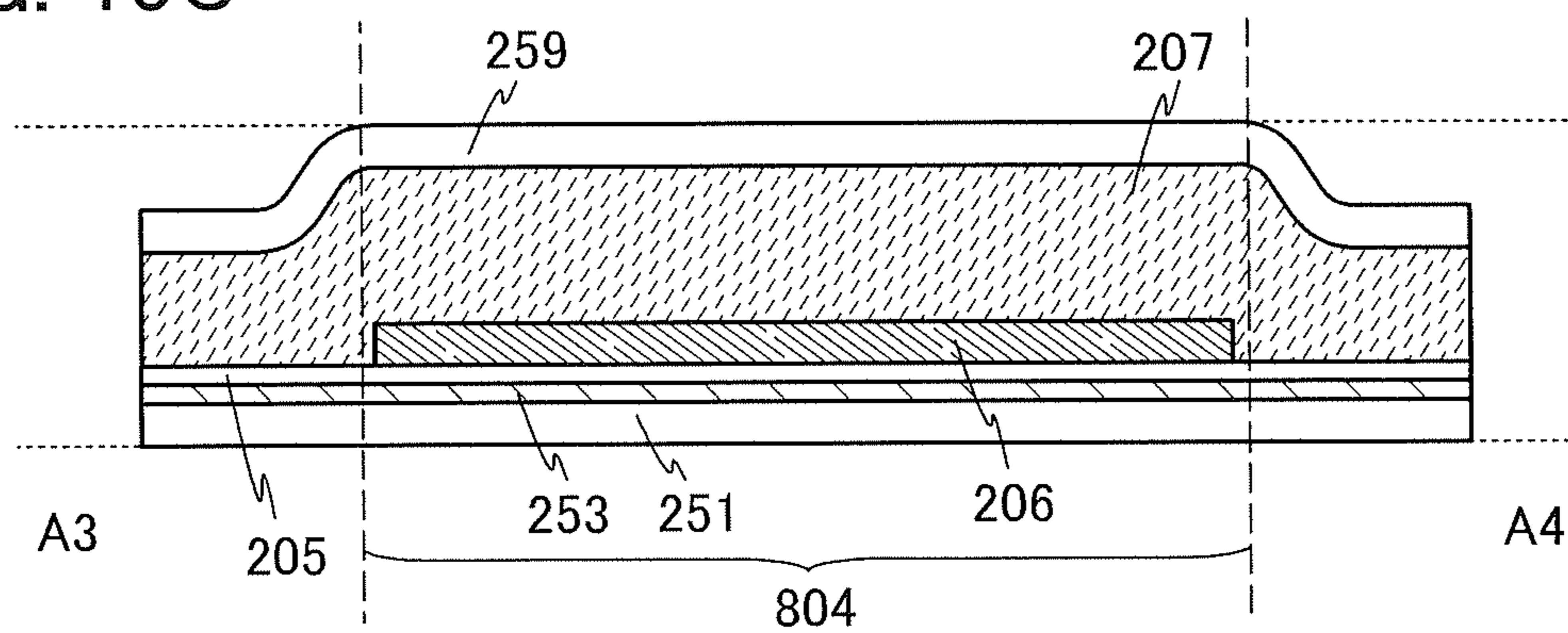


FIG. 15D

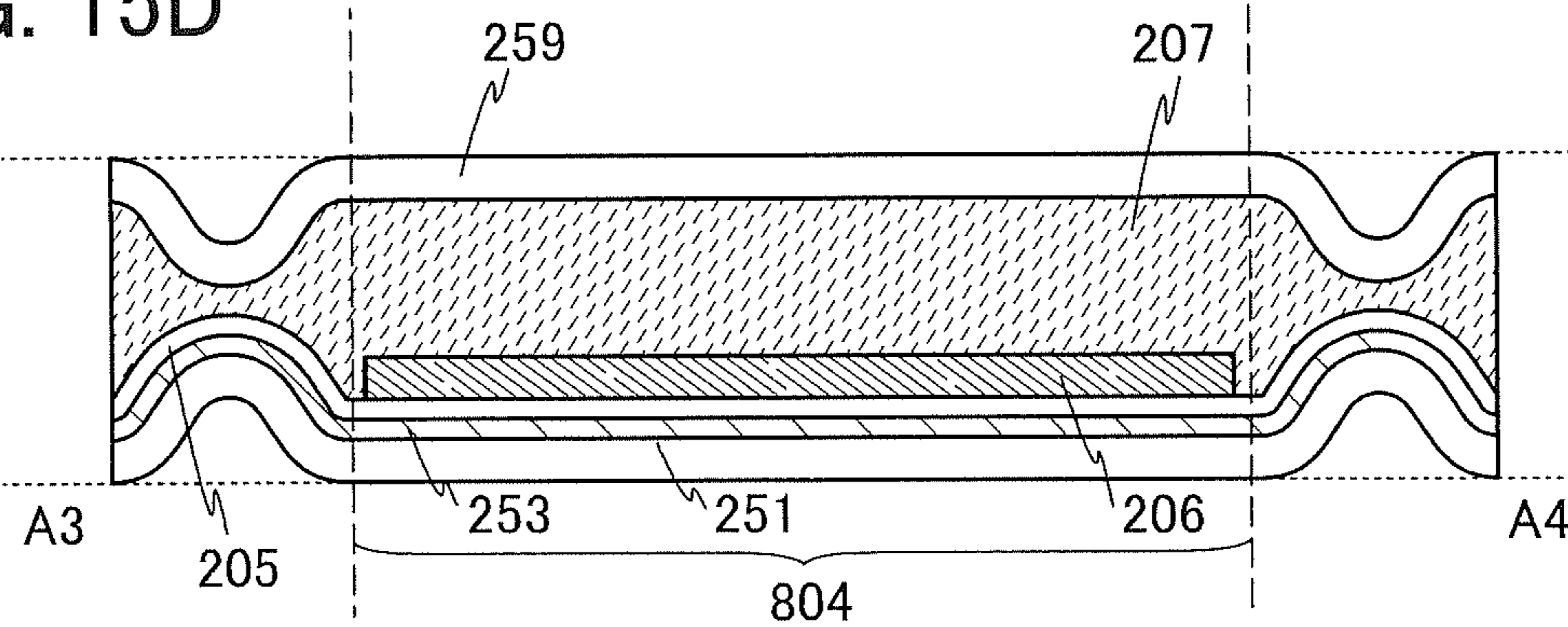


FIG. 16A

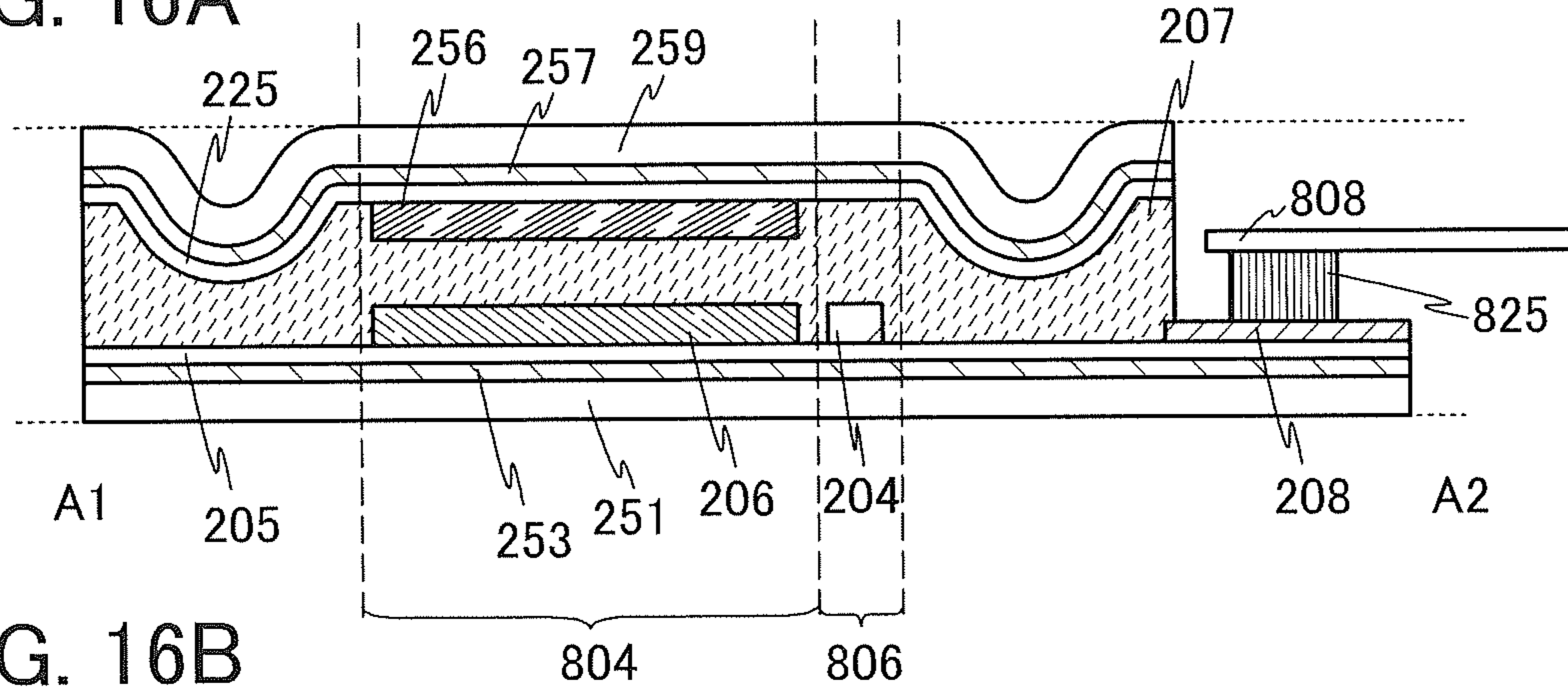


FIG. 16B

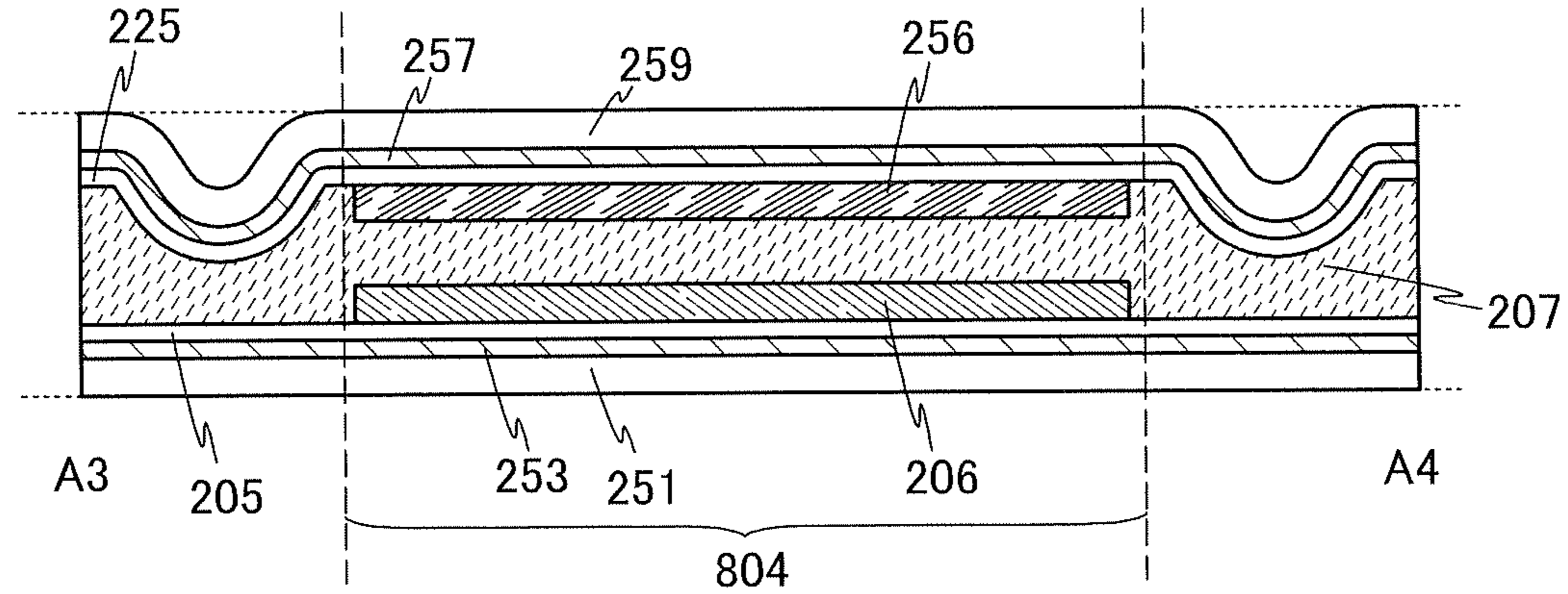


FIG. 16C

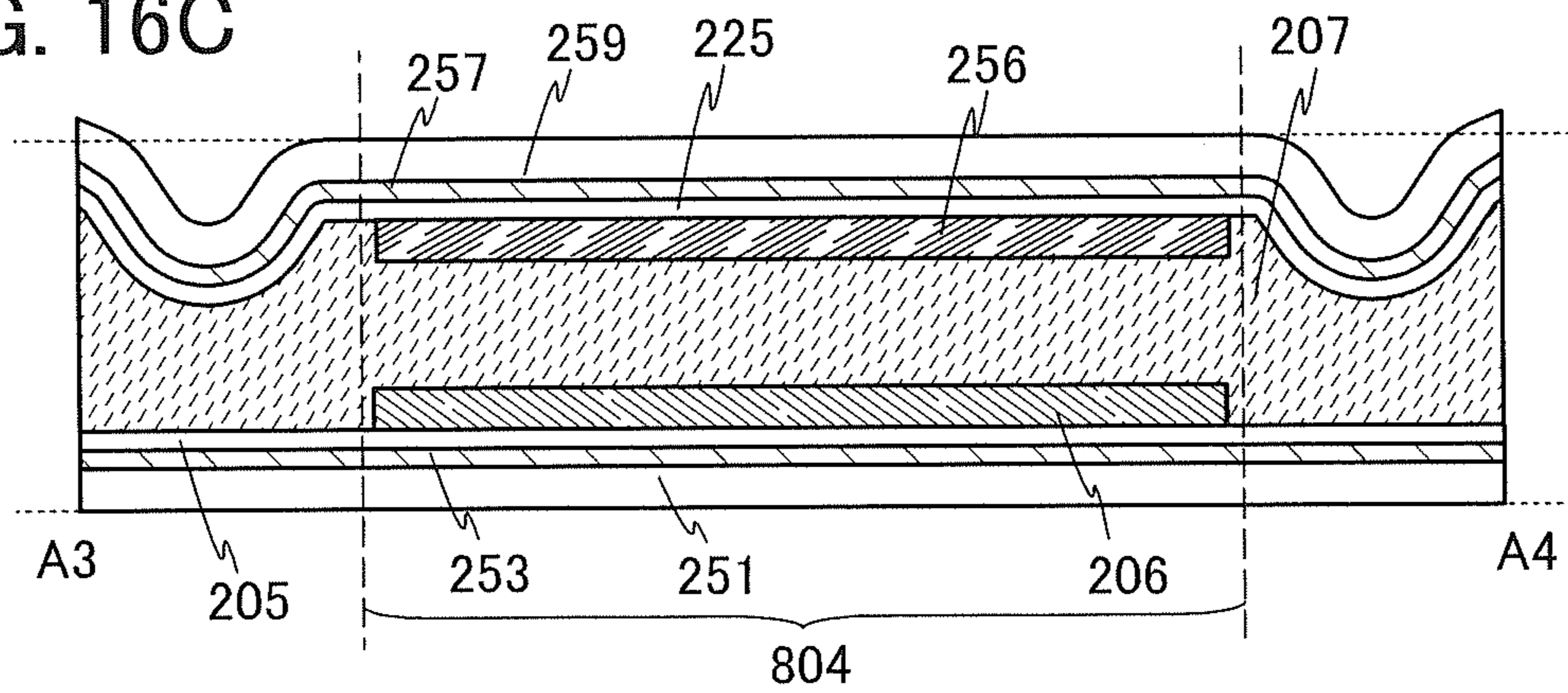


FIG. 16D

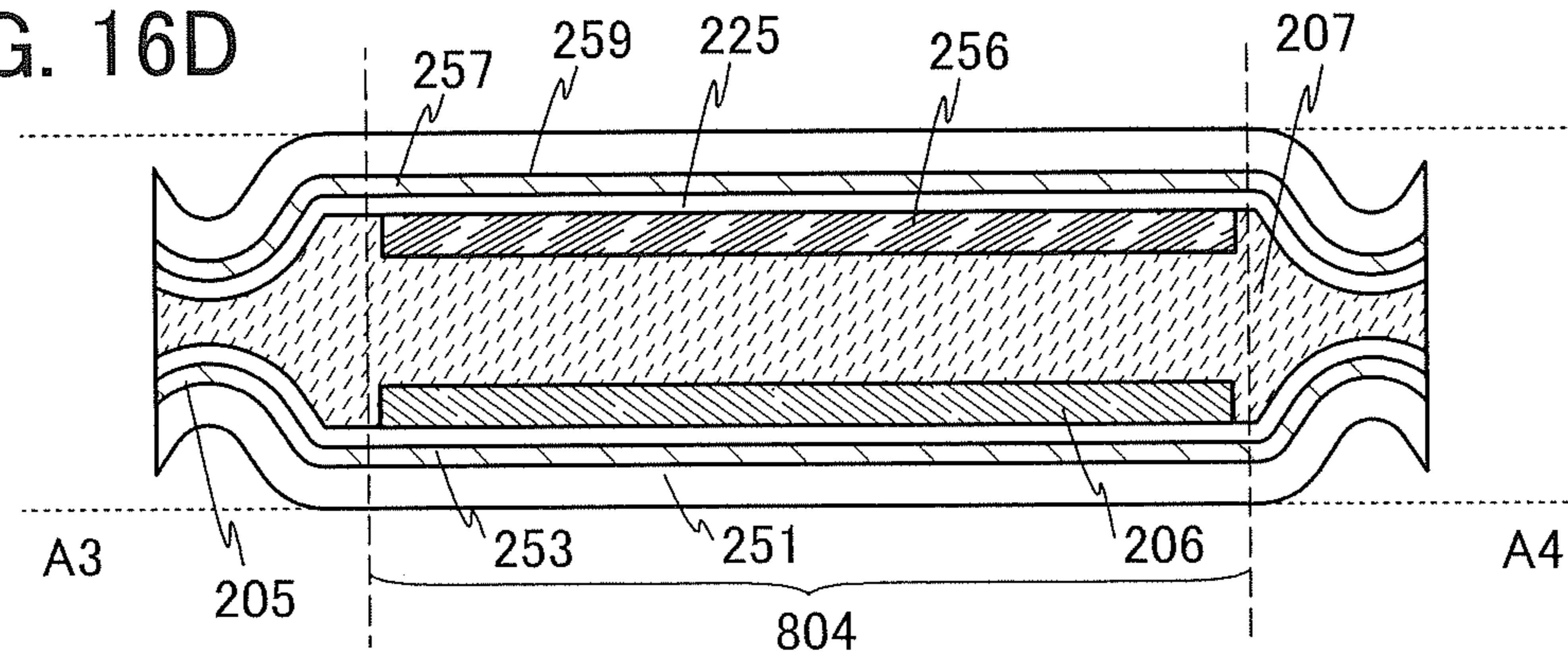


FIG. 17A

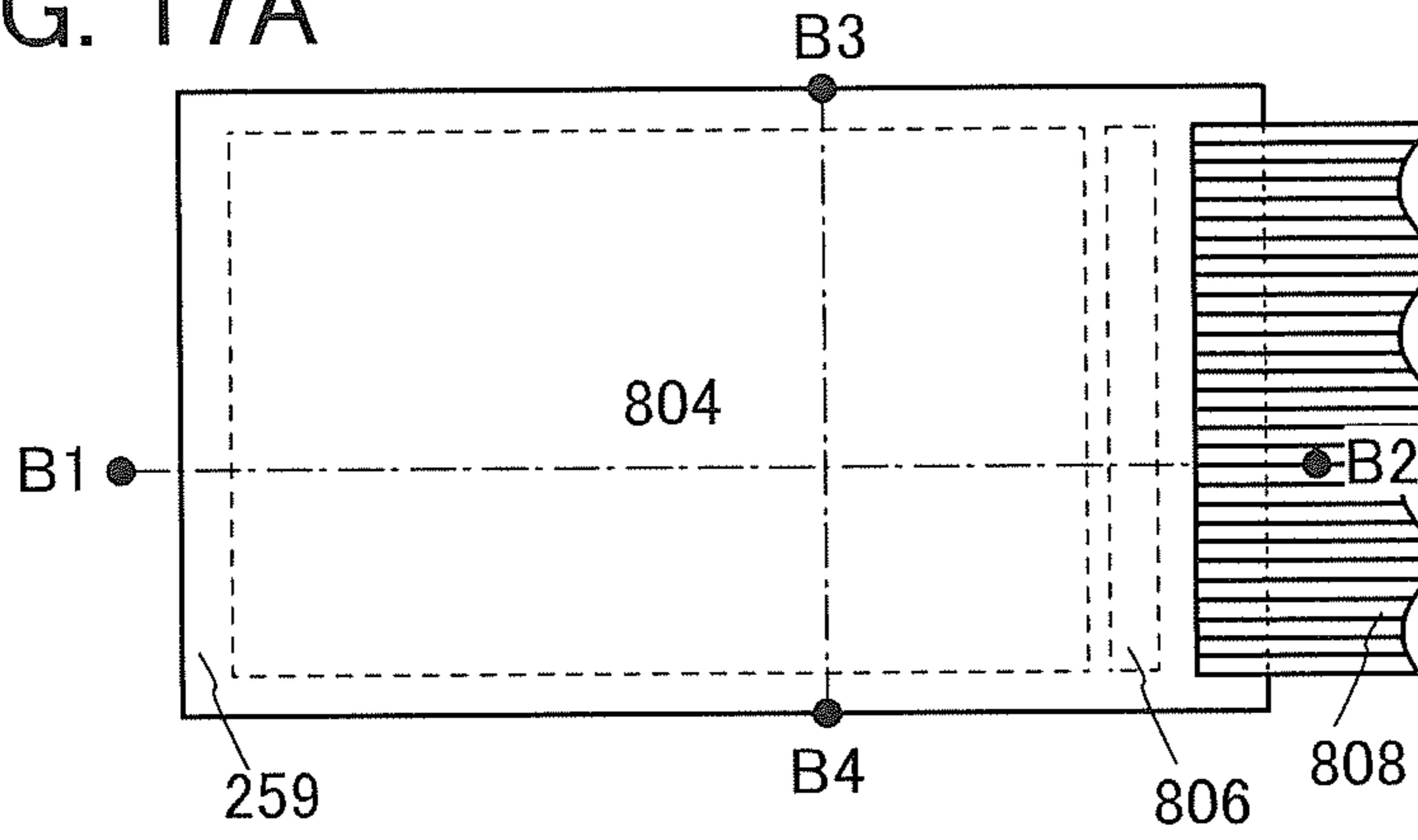


FIG. 17B

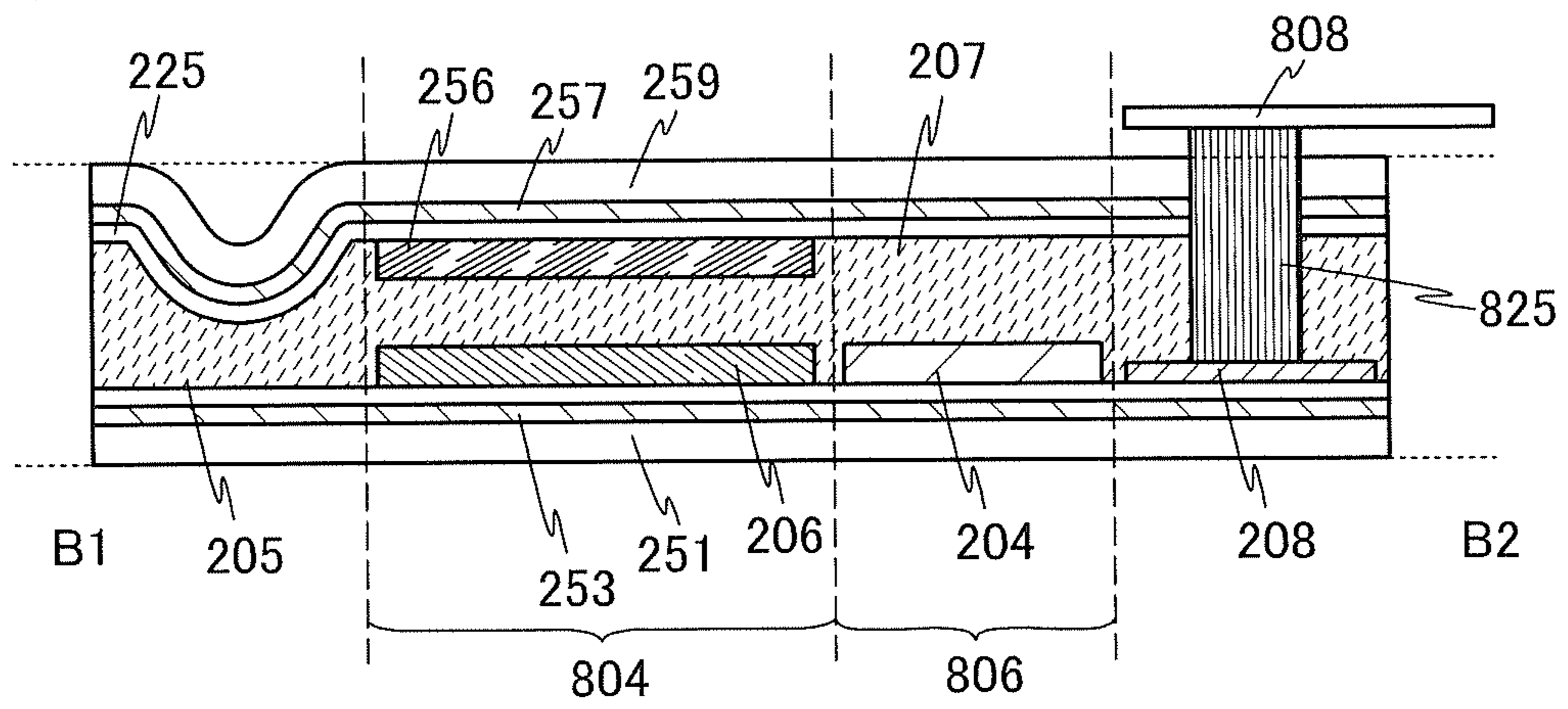


FIG. 17C

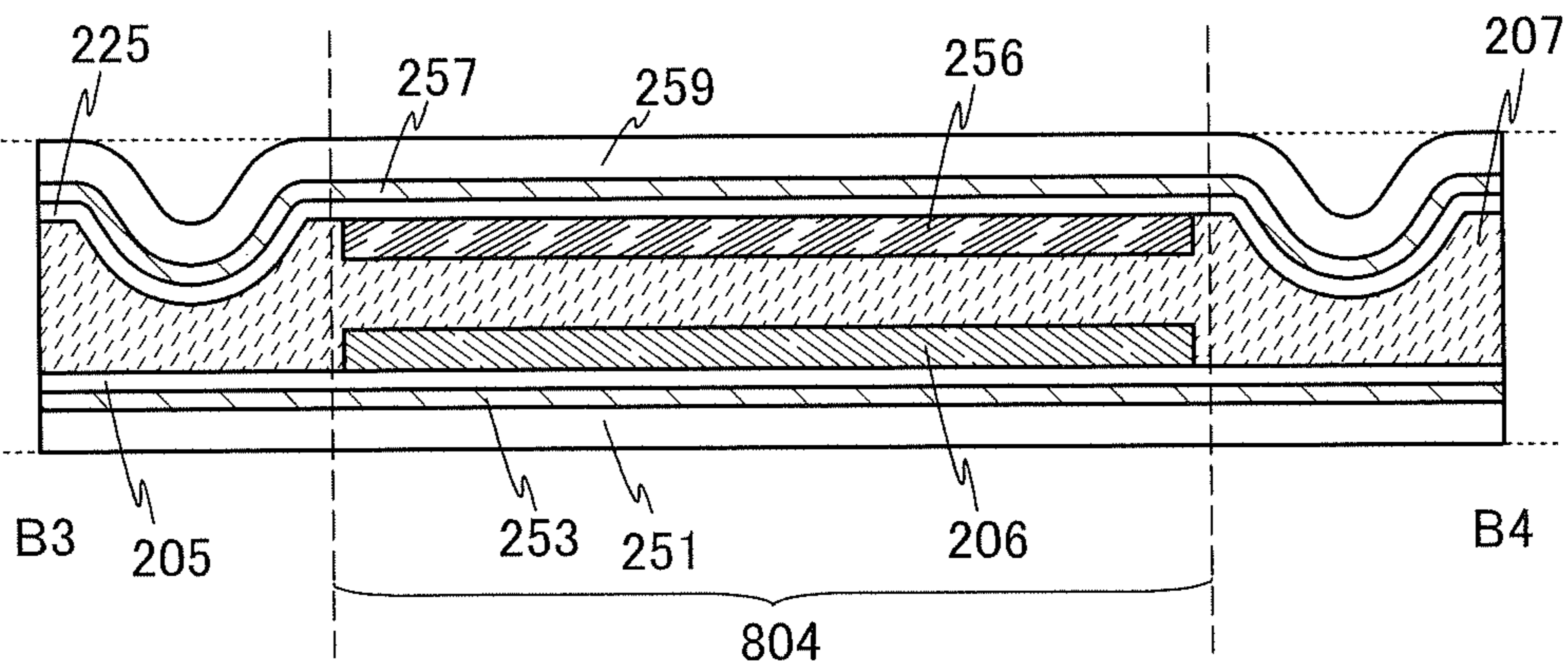


FIG. 18A

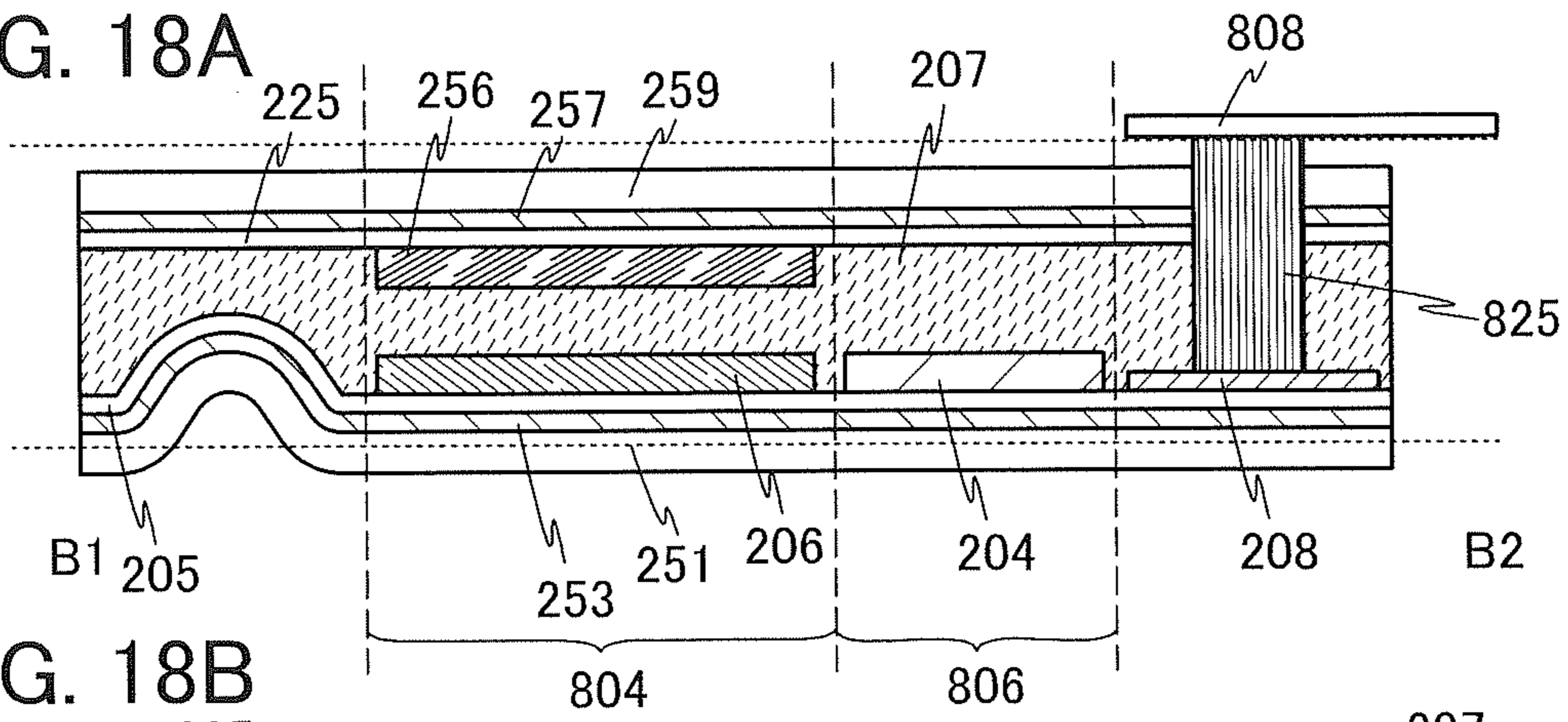


FIG. 18B

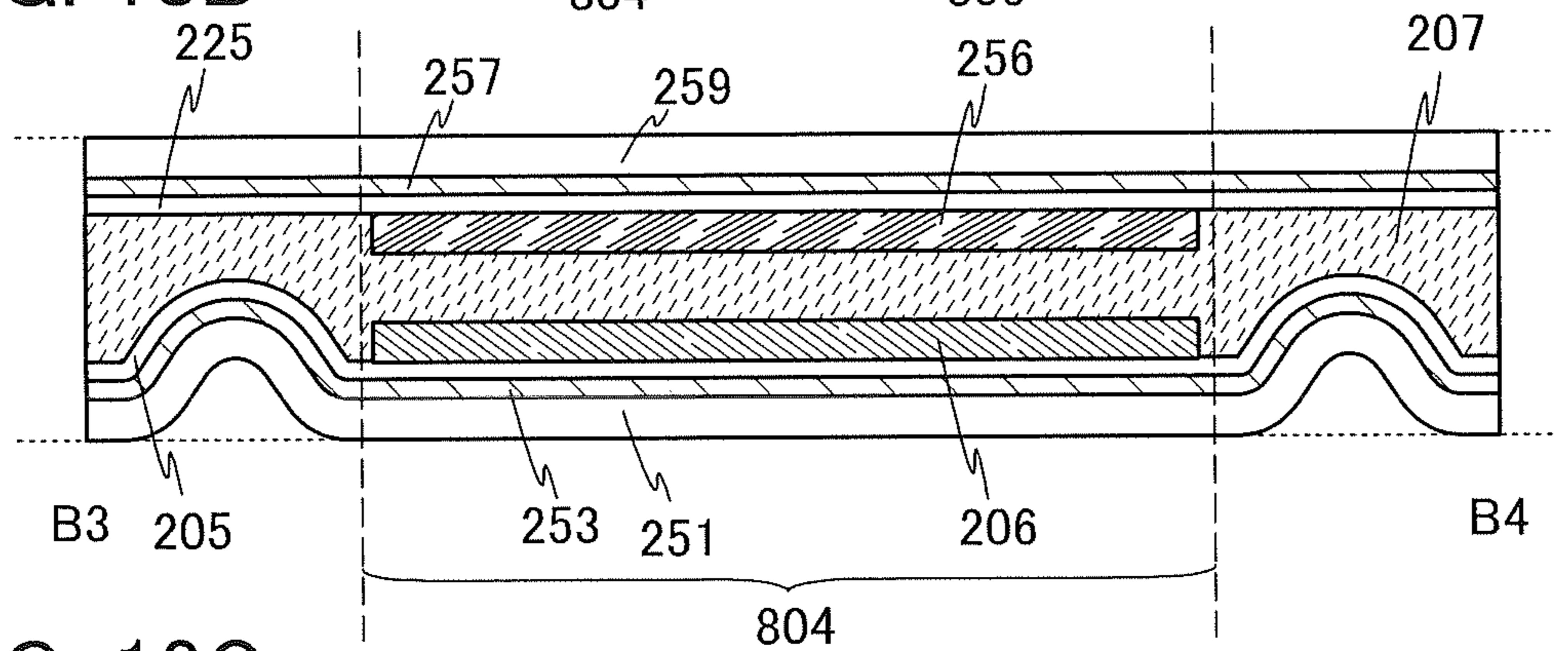


FIG. 18C

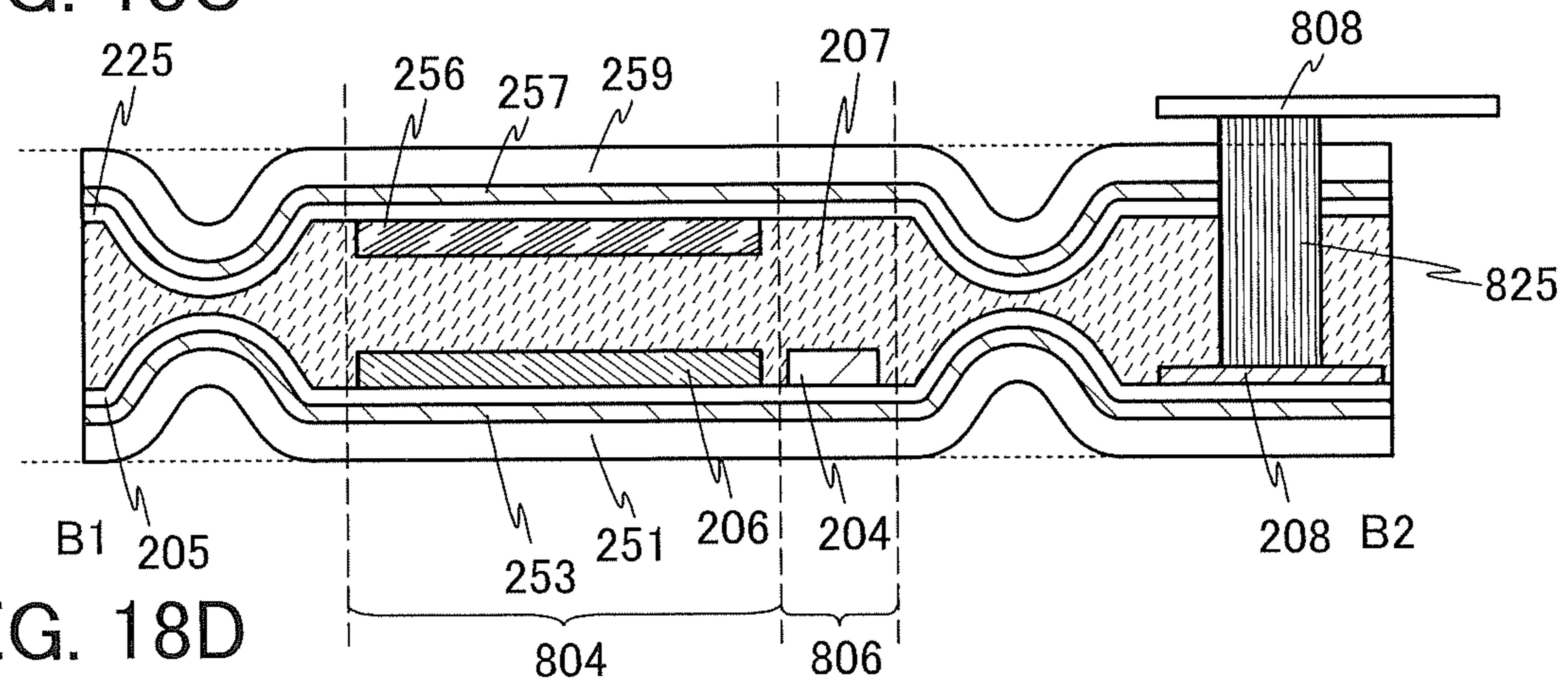


FIG. 18D

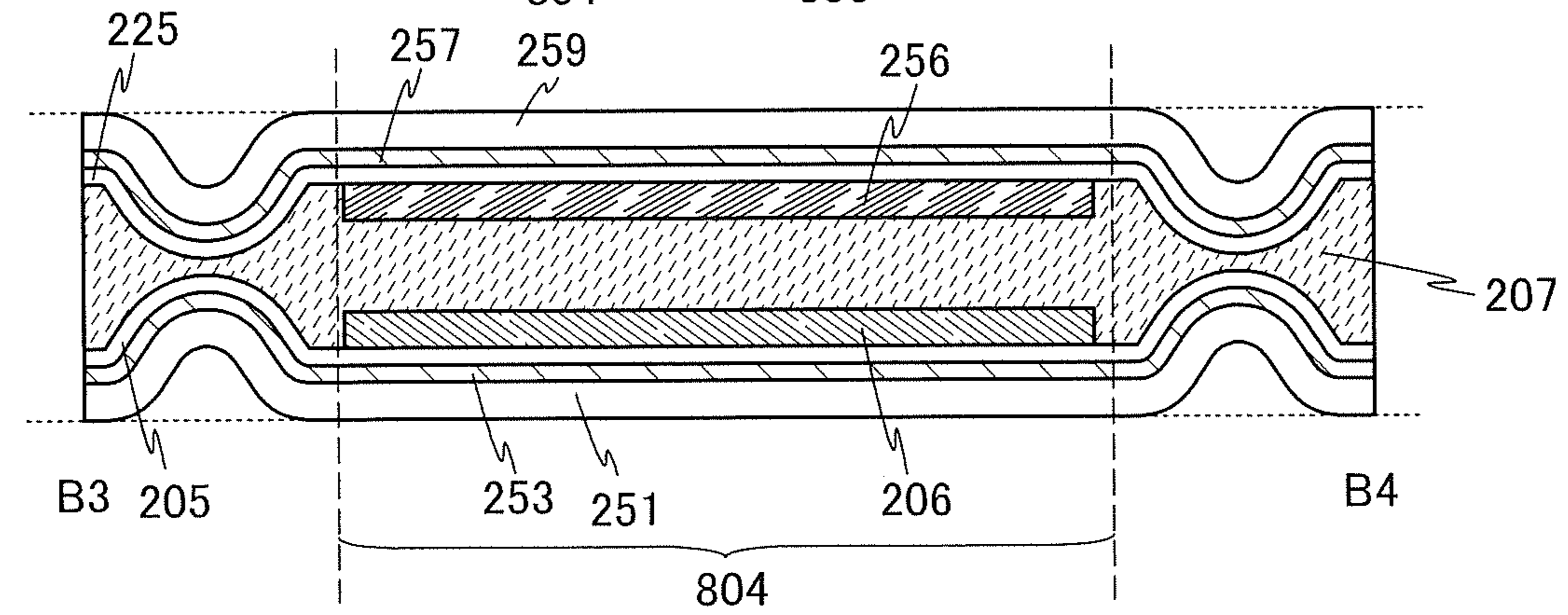


FIG. 19A

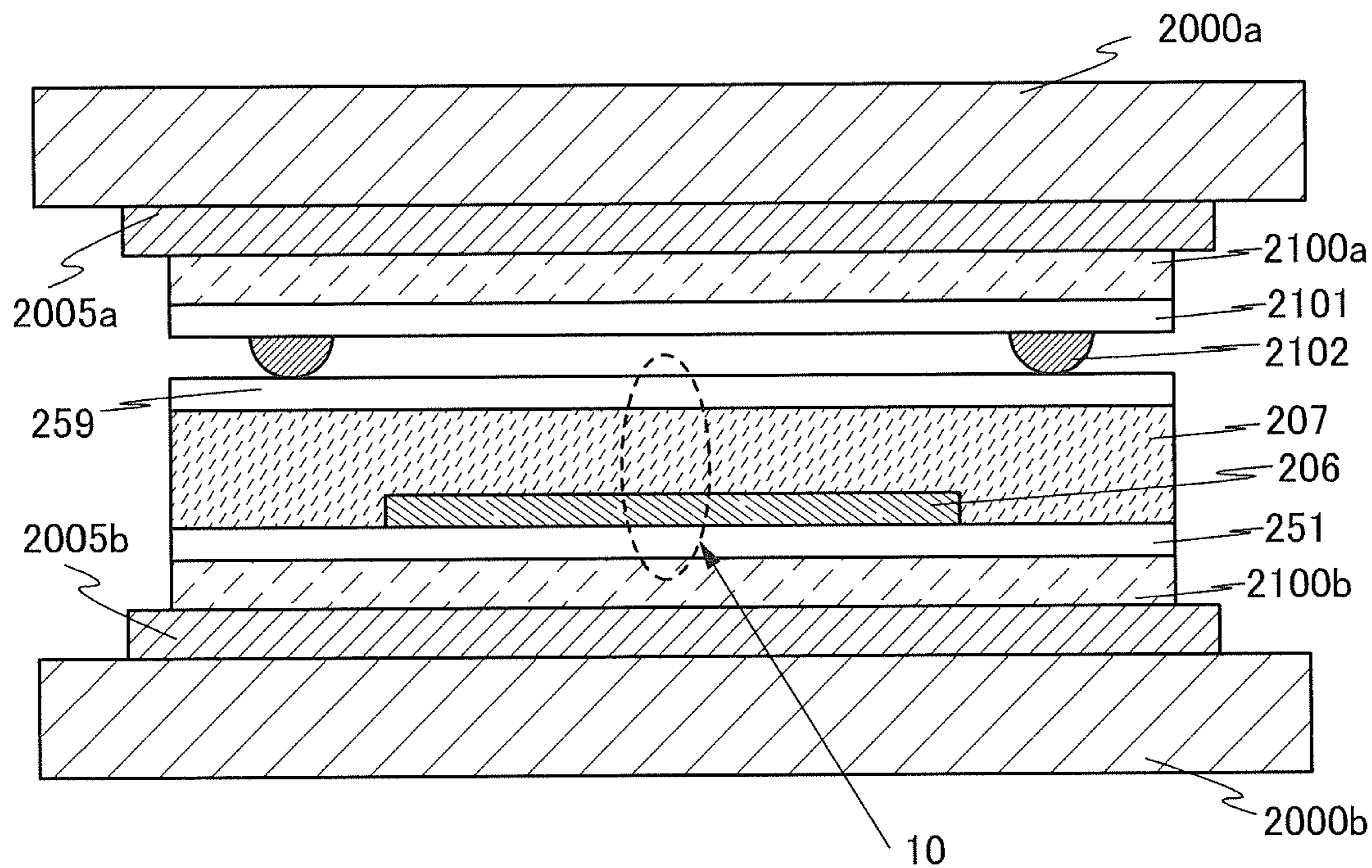


FIG. 19B

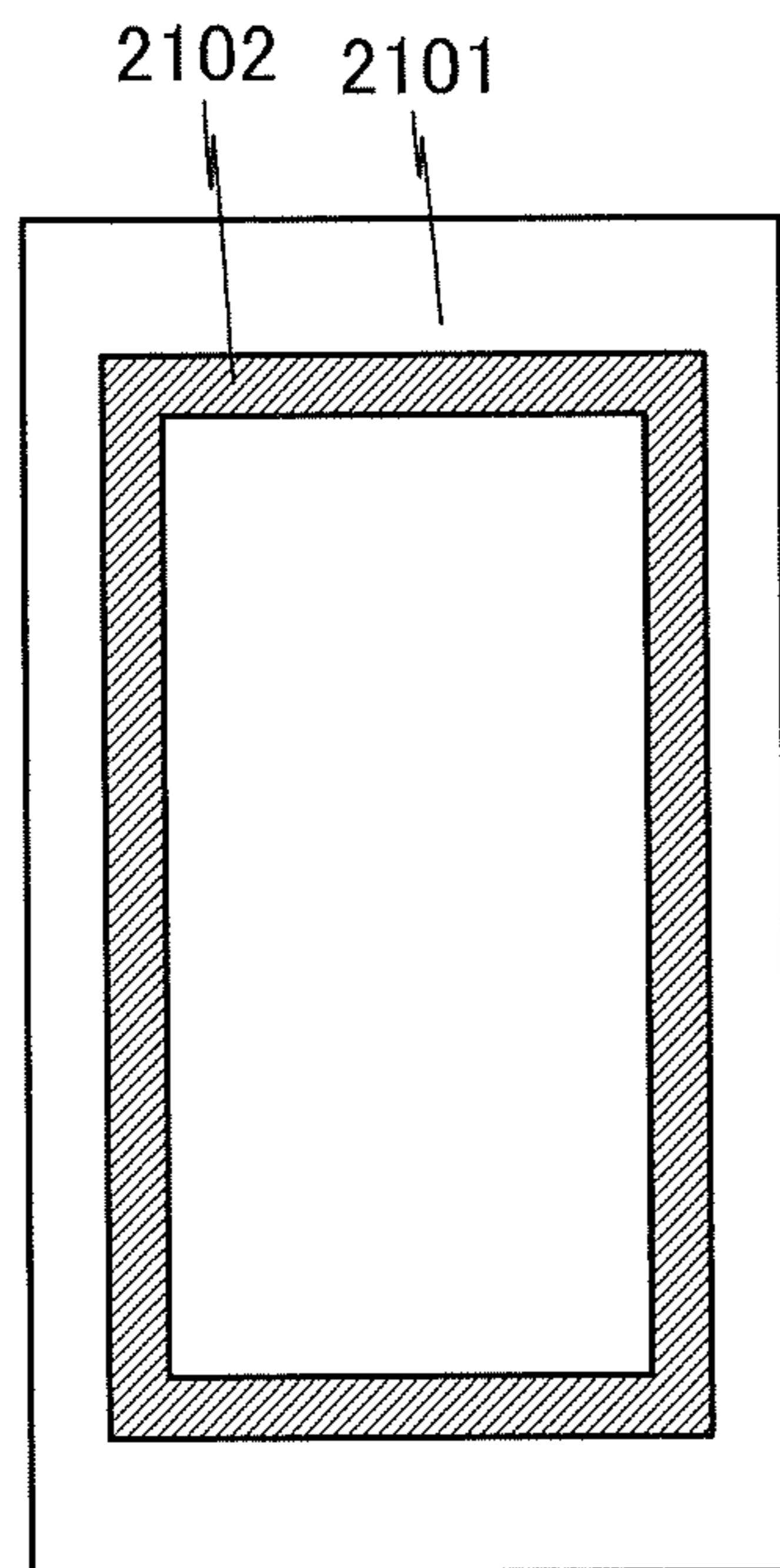


FIG. 19C

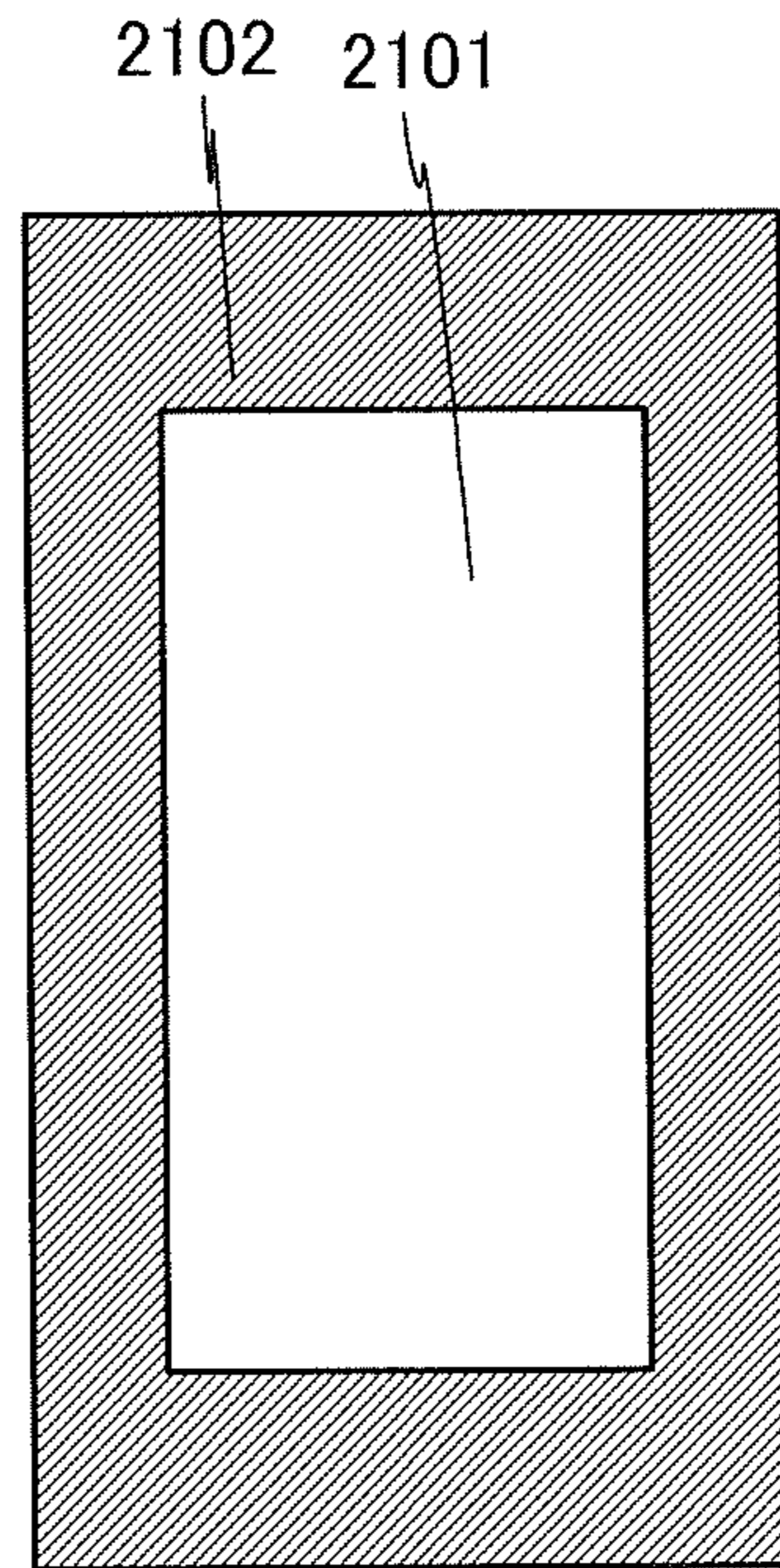


FIG. 19D

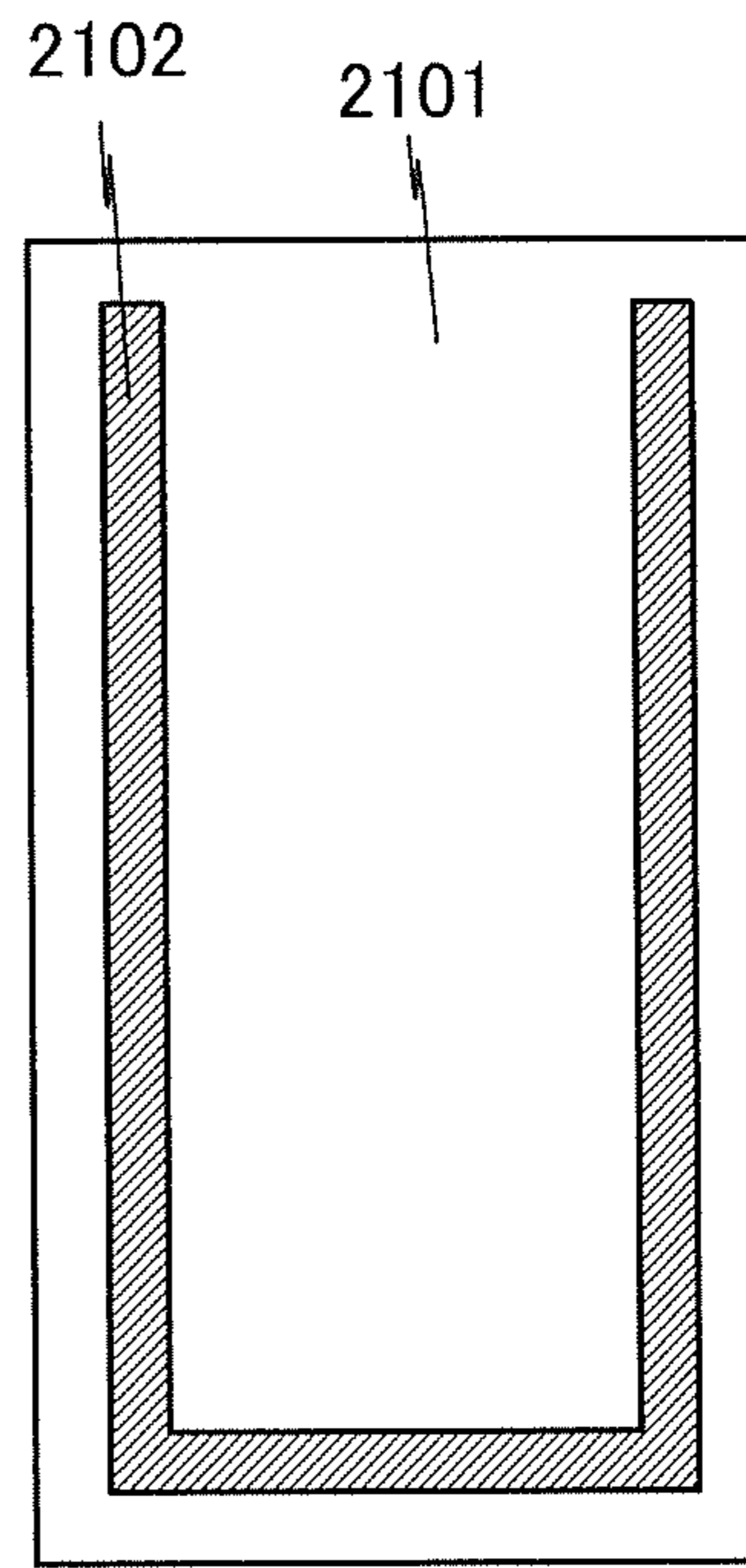


FIG. 20A

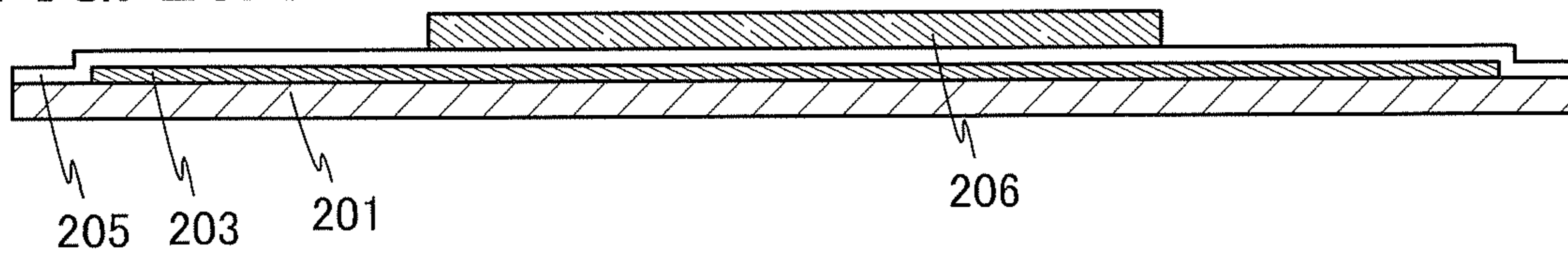


FIG. 20B

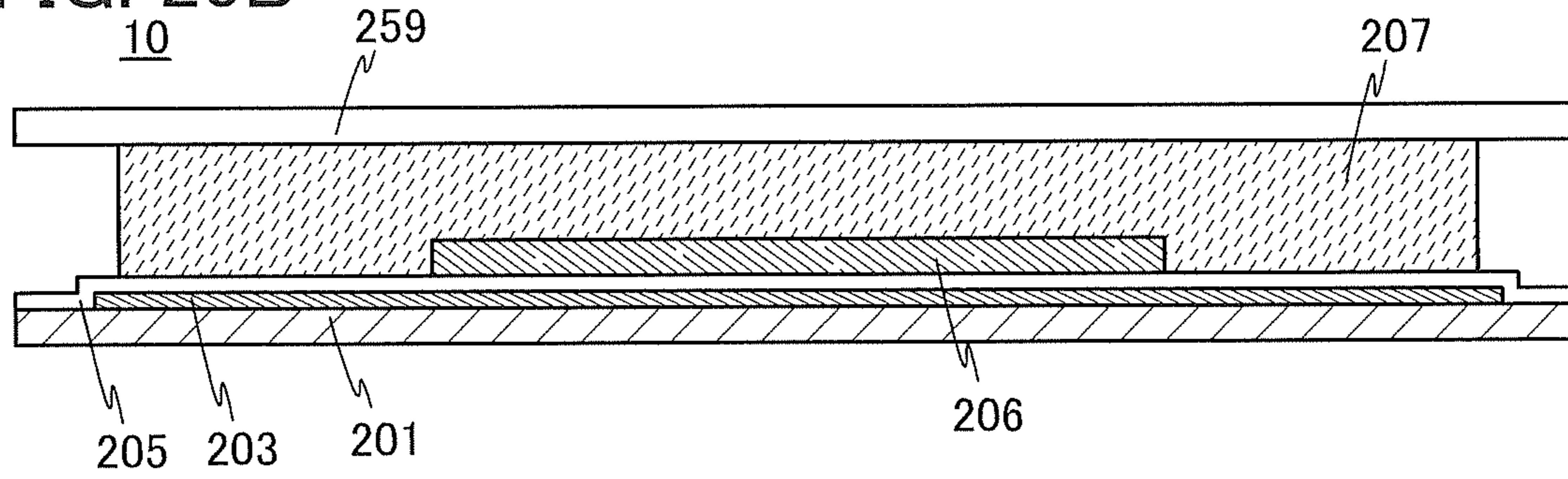


FIG. 20C

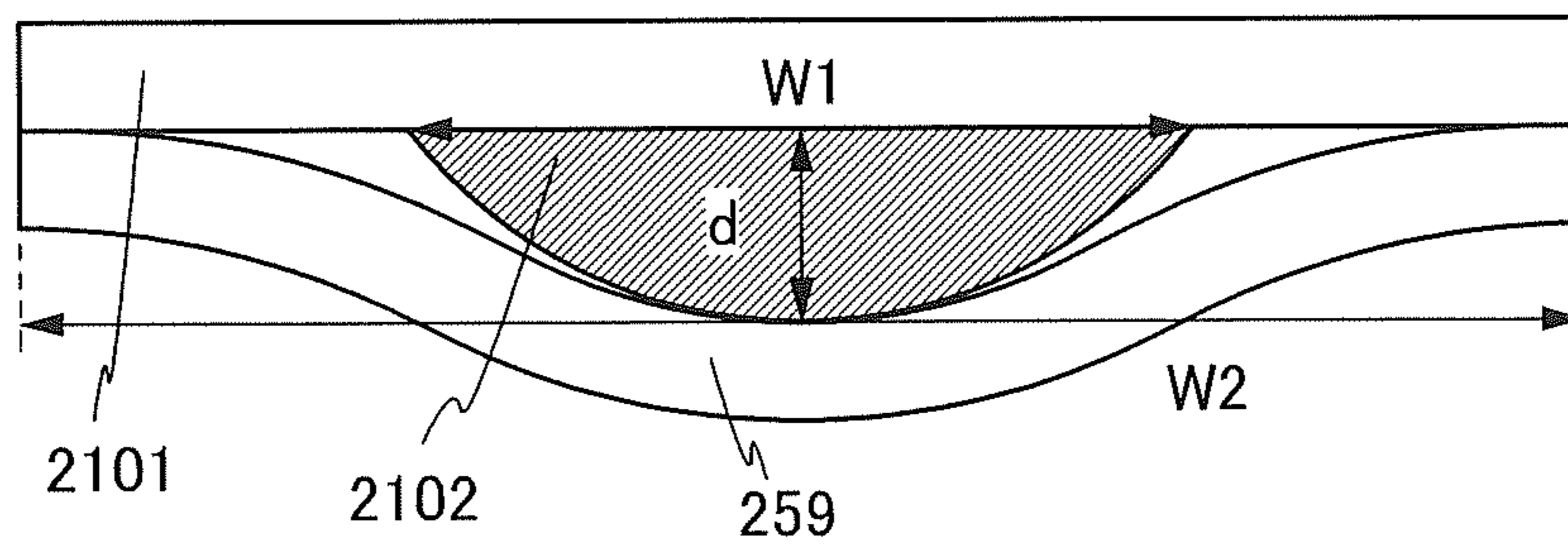


FIG. 20D

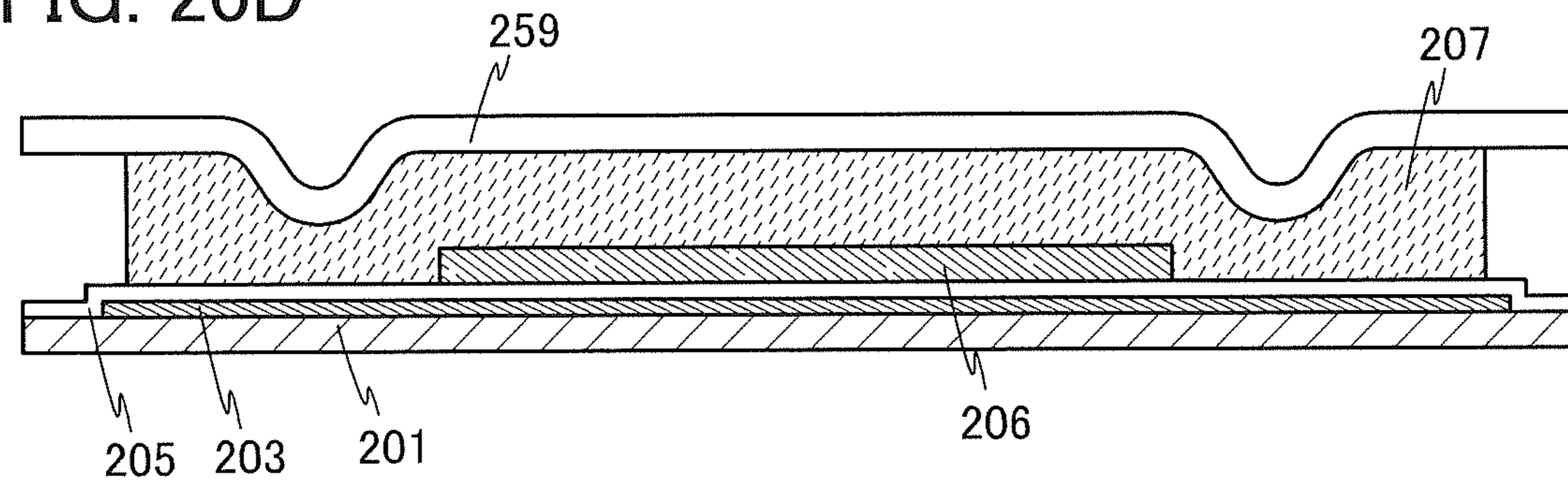


FIG. 21A

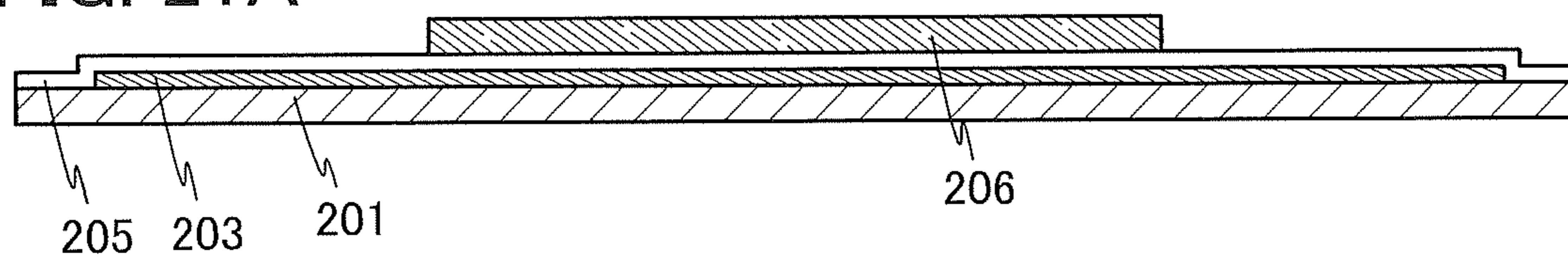


FIG. 21B

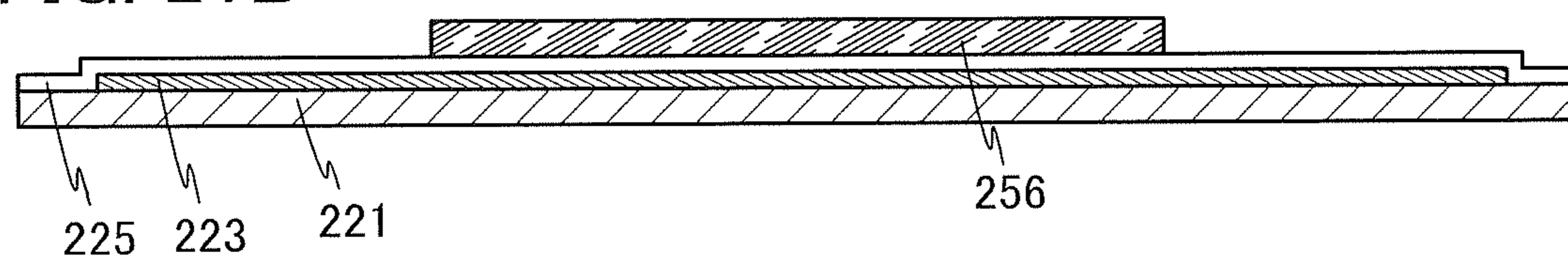


FIG. 21C

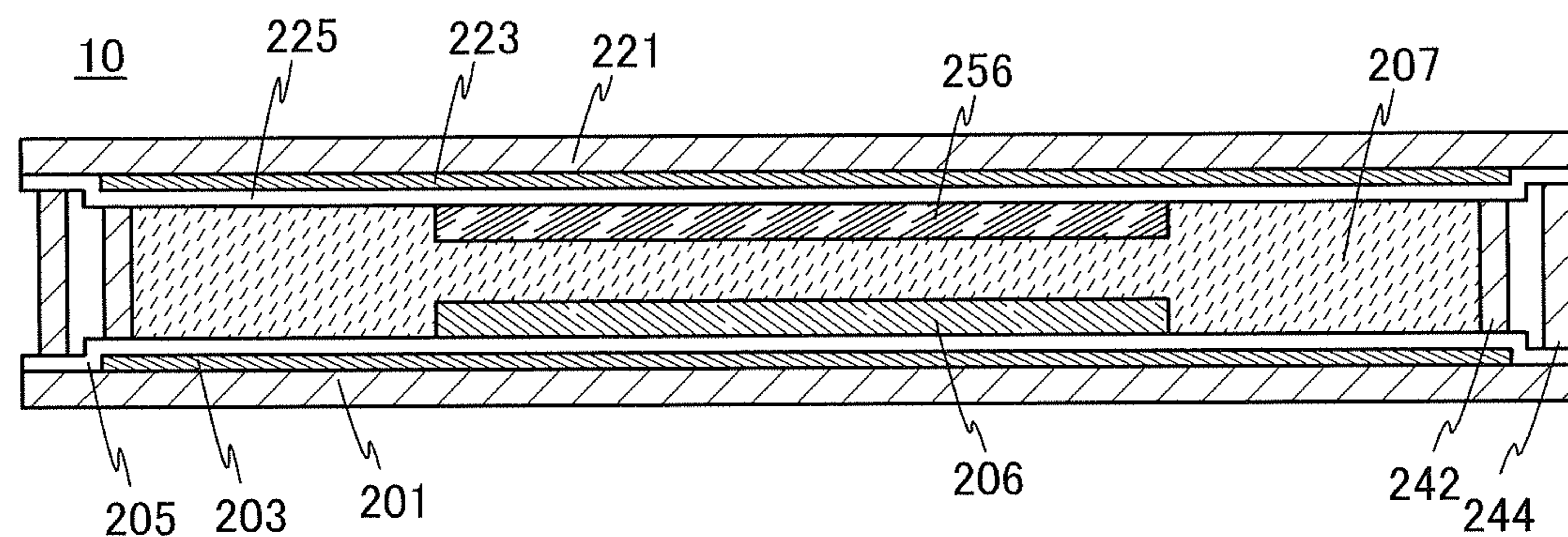


FIG. 21D

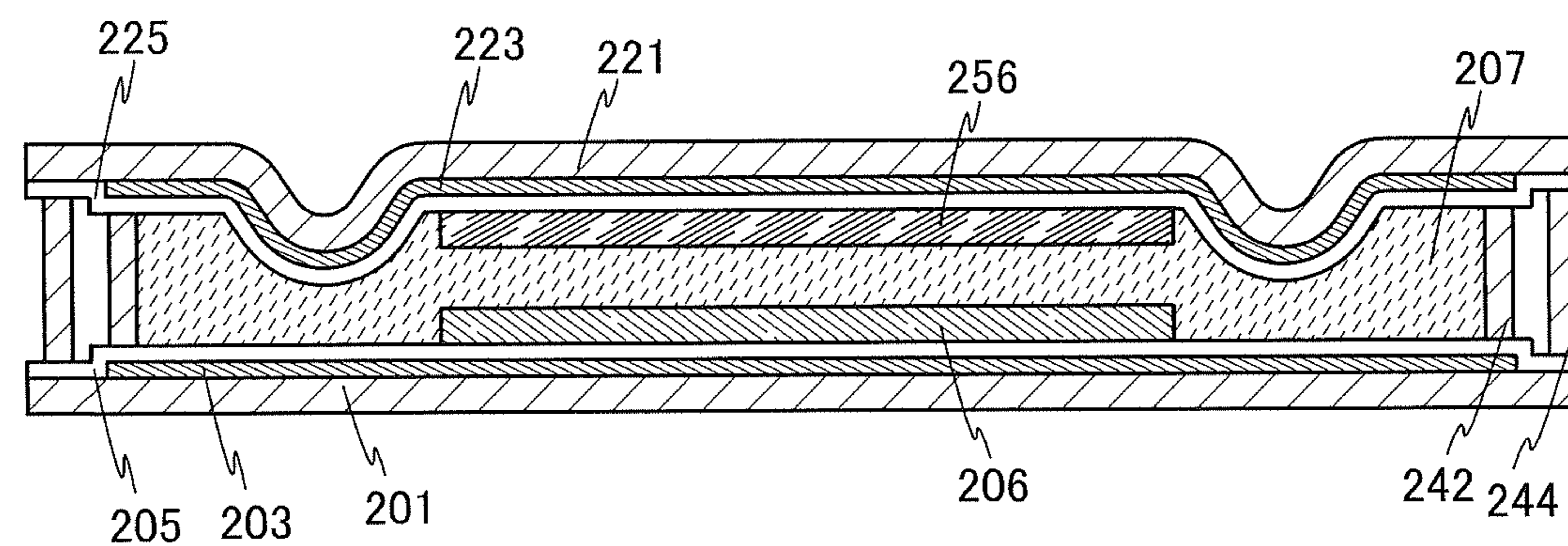




FIG. 22A

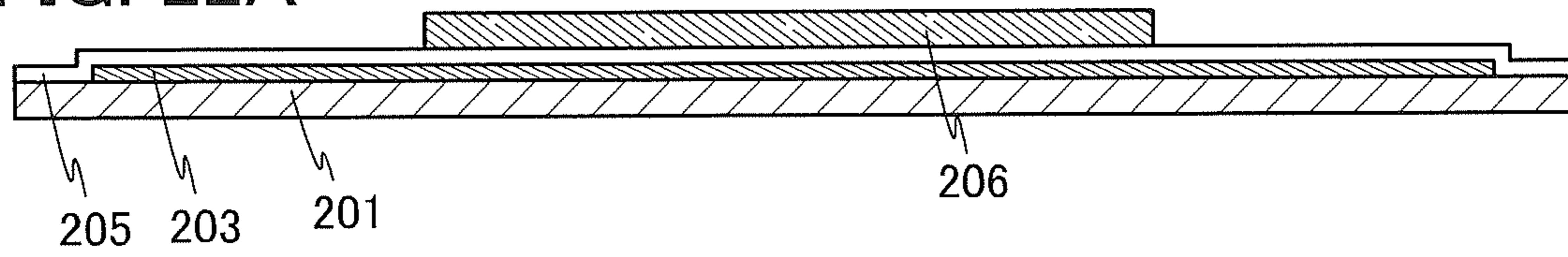


FIG. 22B

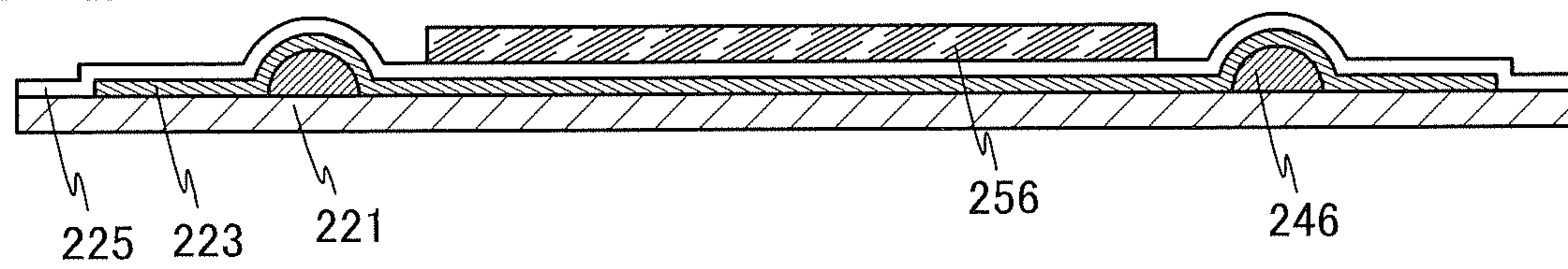


FIG. 22C

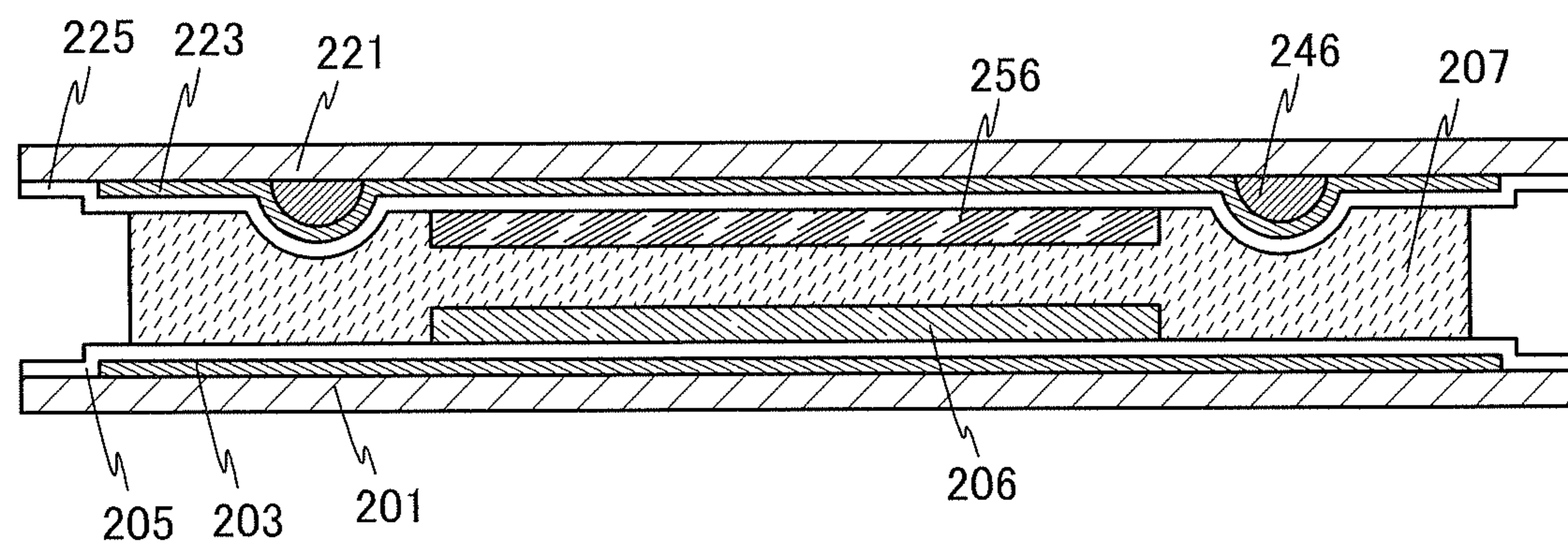


FIG. 22D

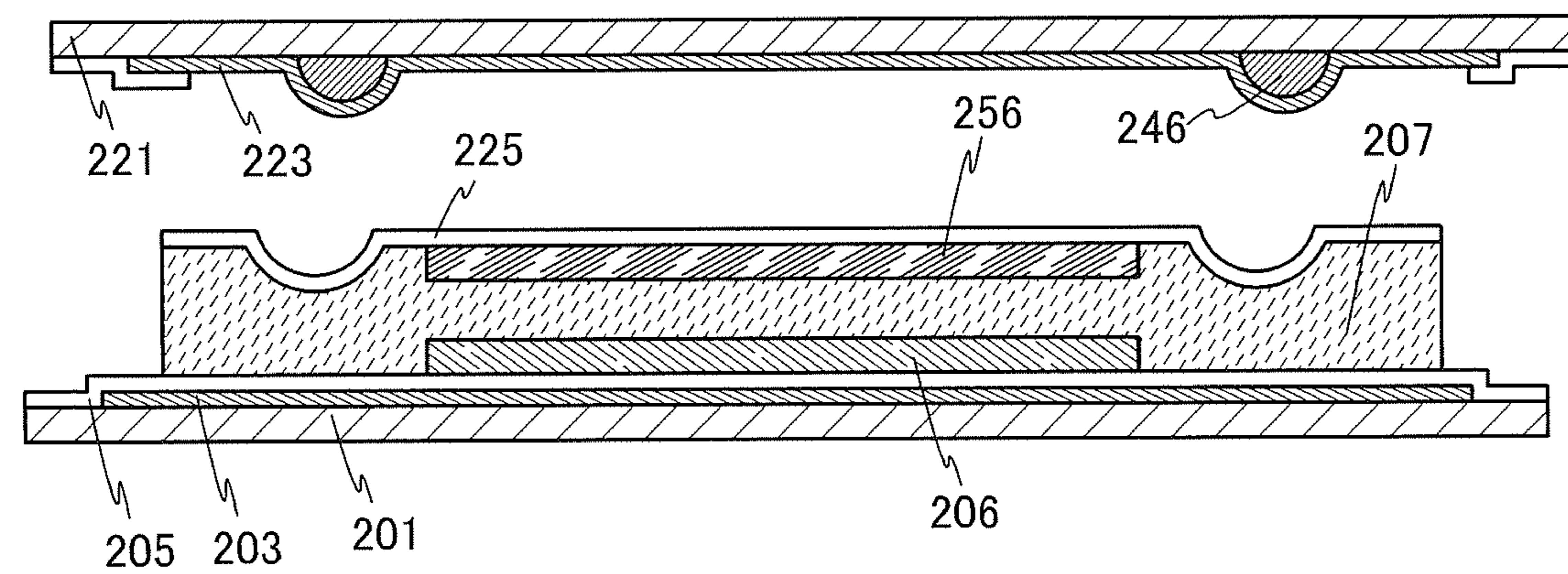


FIG. 23A1

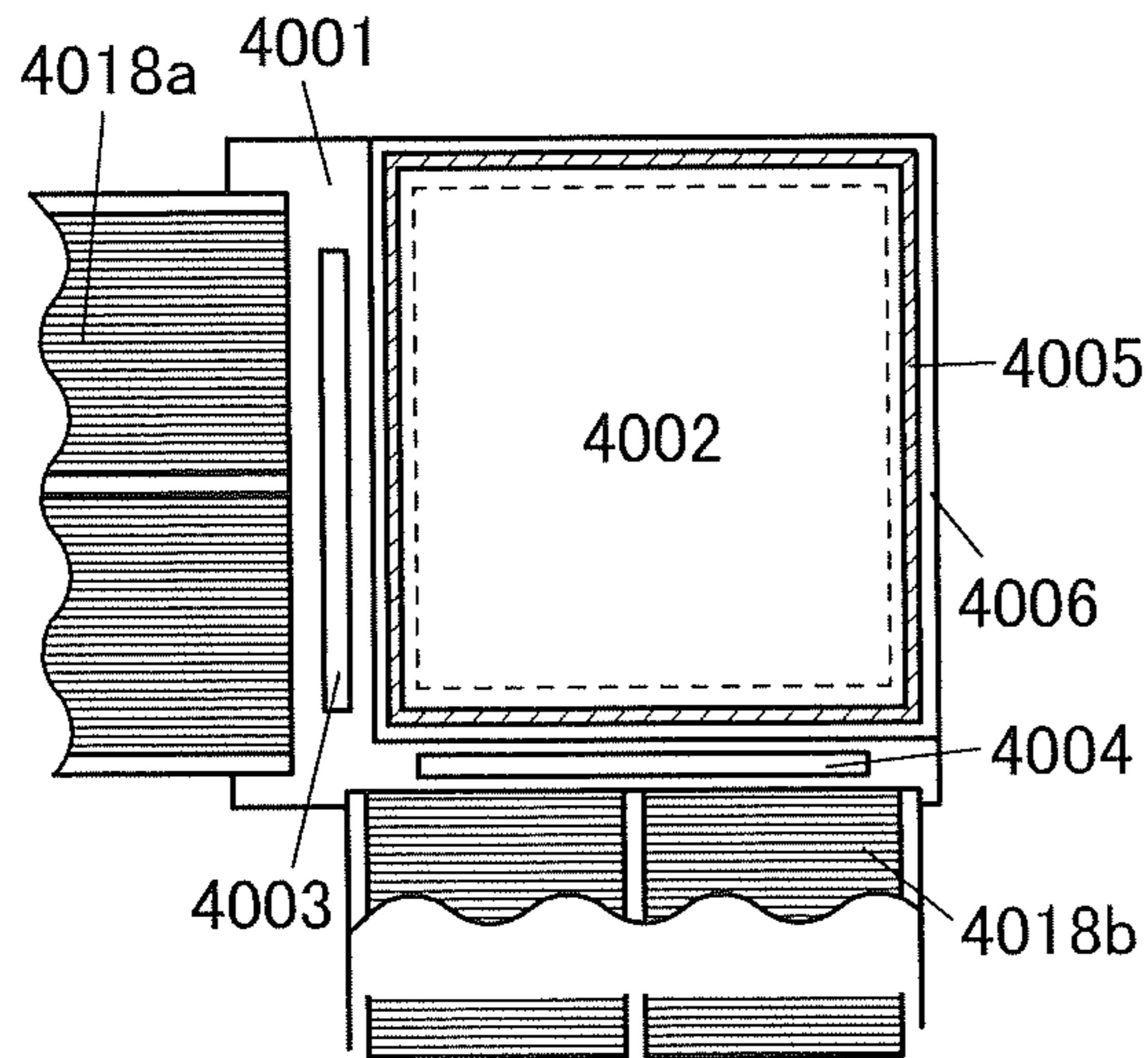


FIG. 23A2

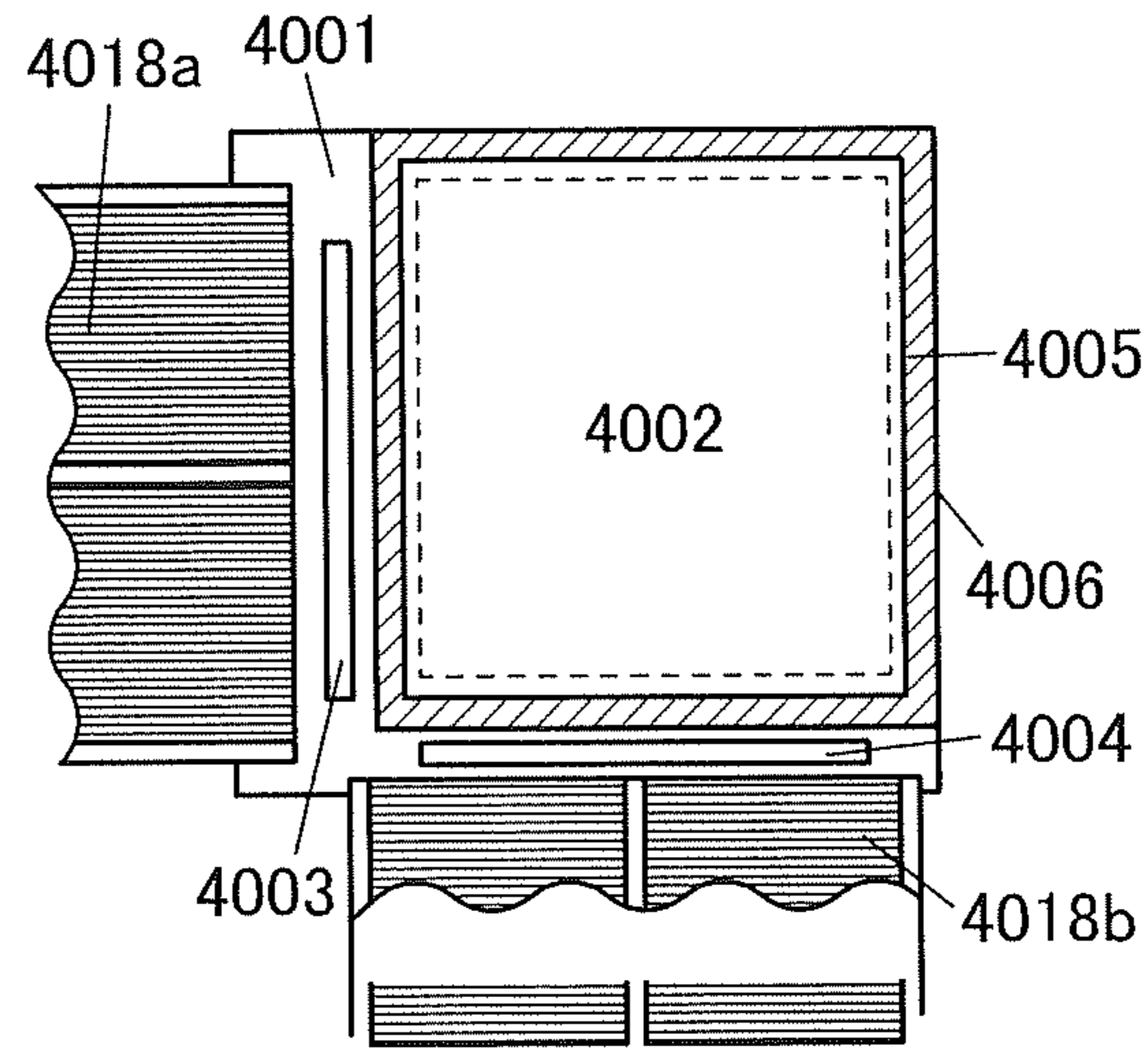


FIG. 23B1

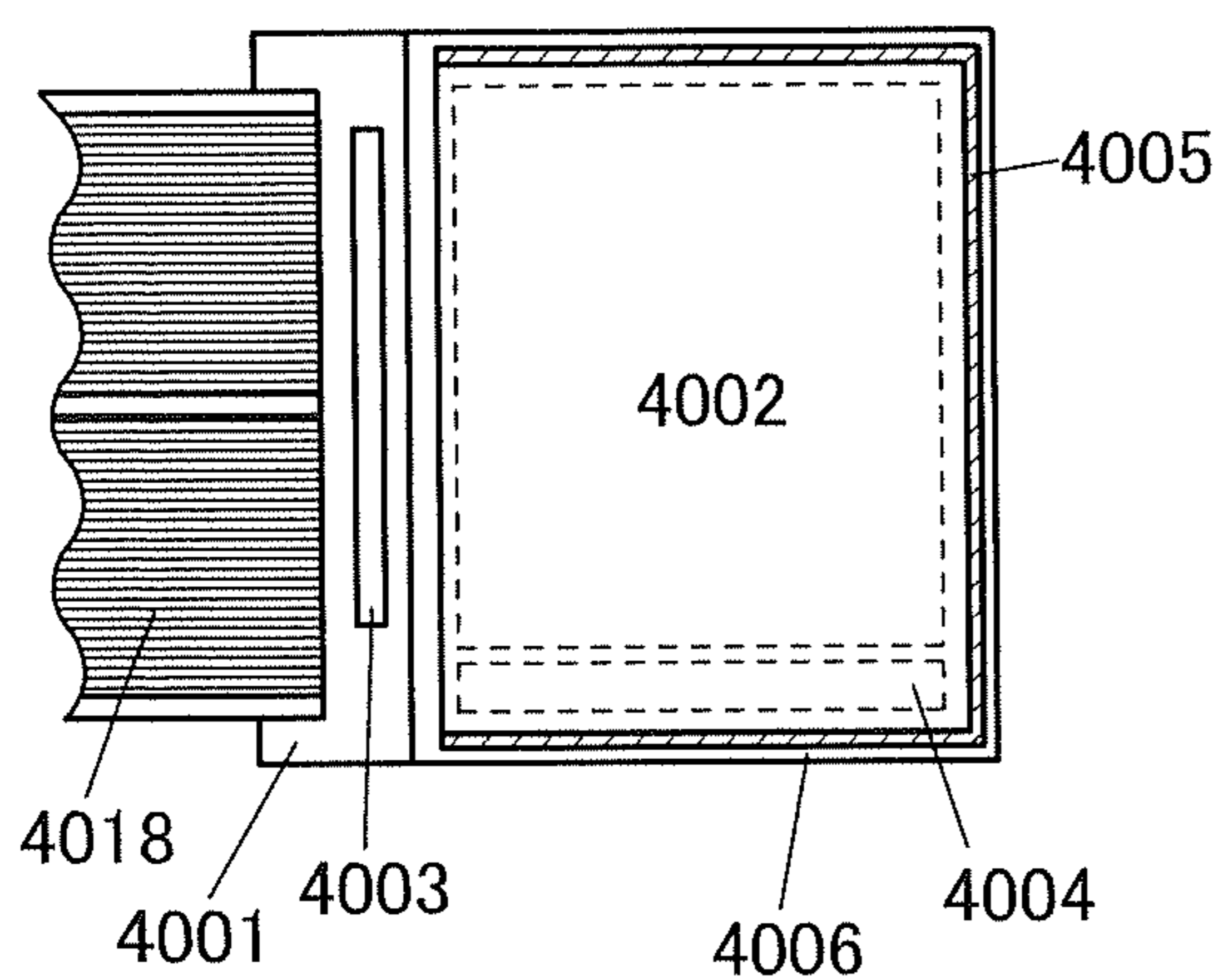


FIG. 23B2

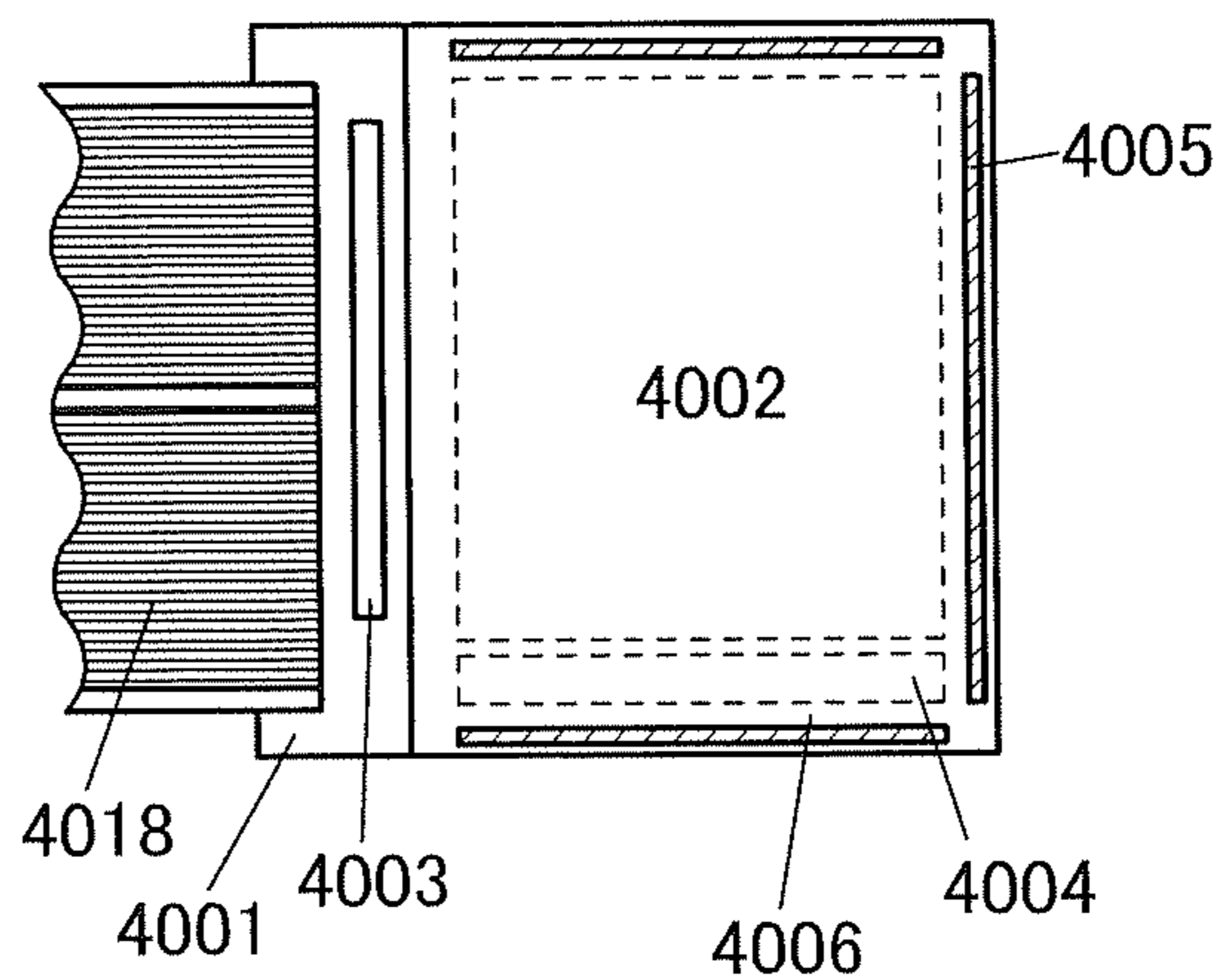


FIG. 23C

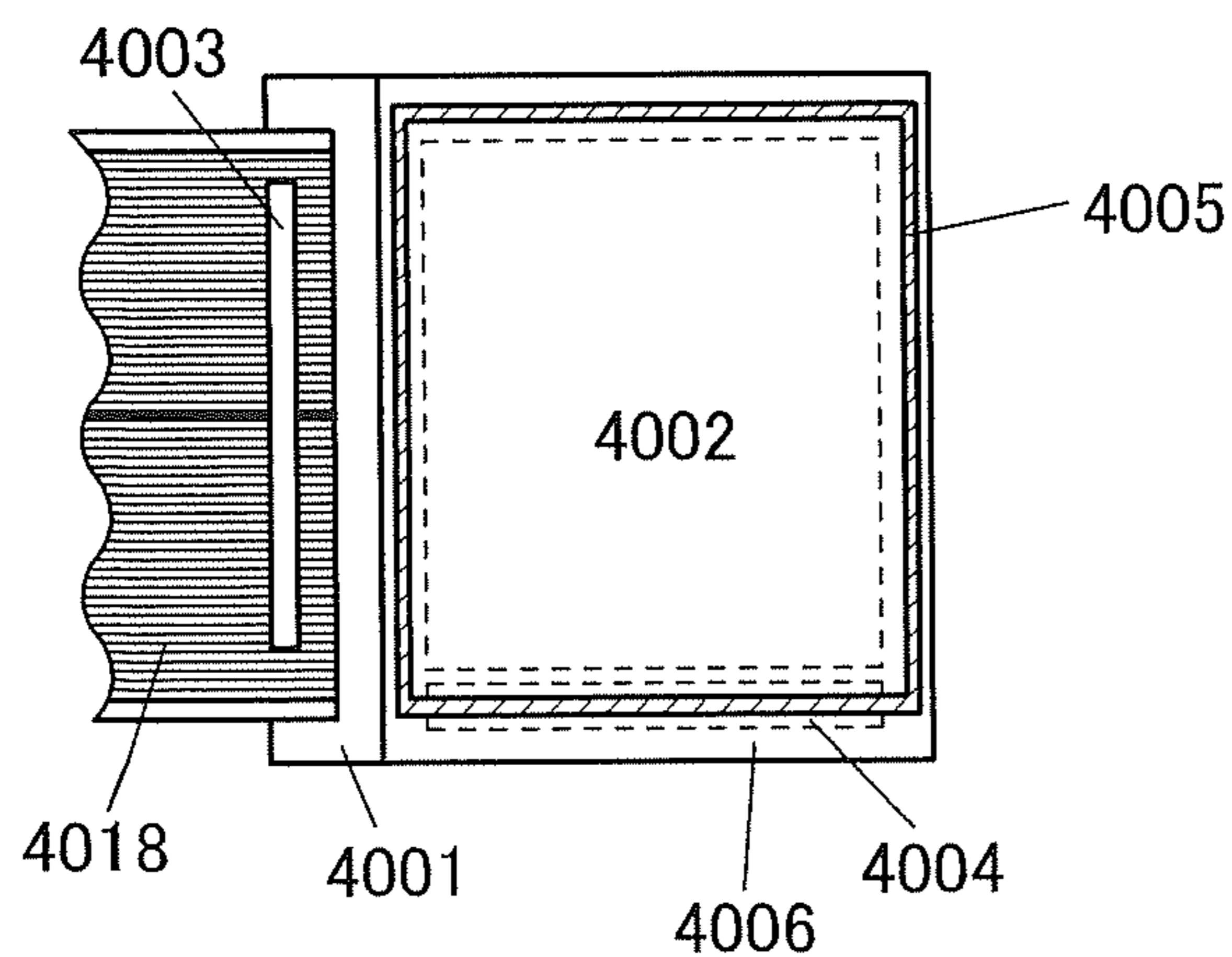


FIG. 24A

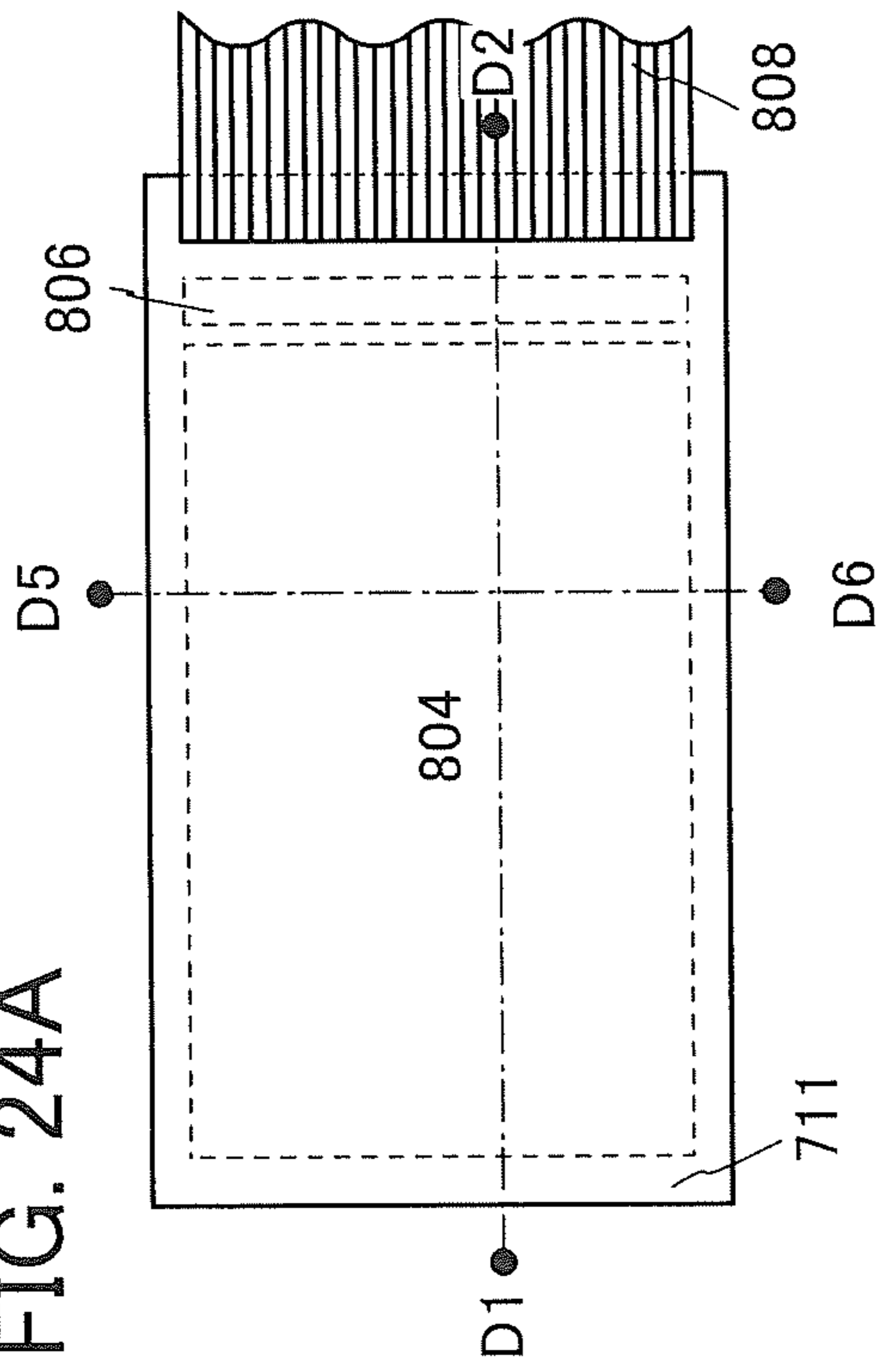


FIG. 24B

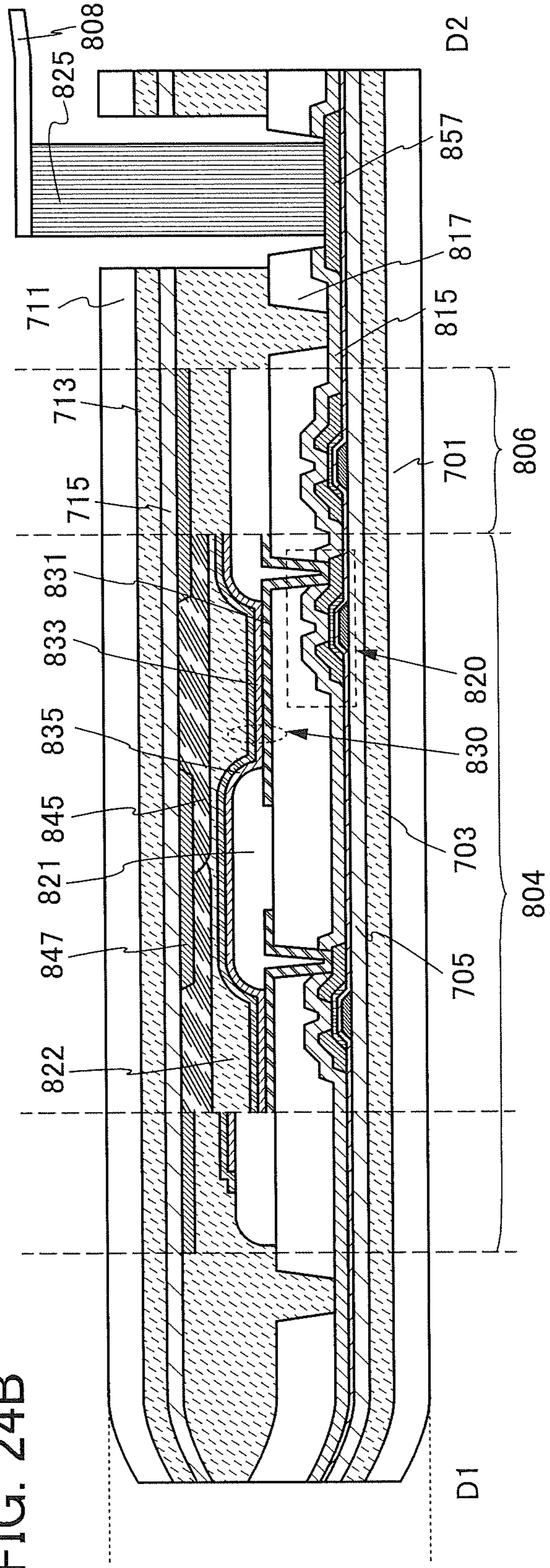


FIG. 25A

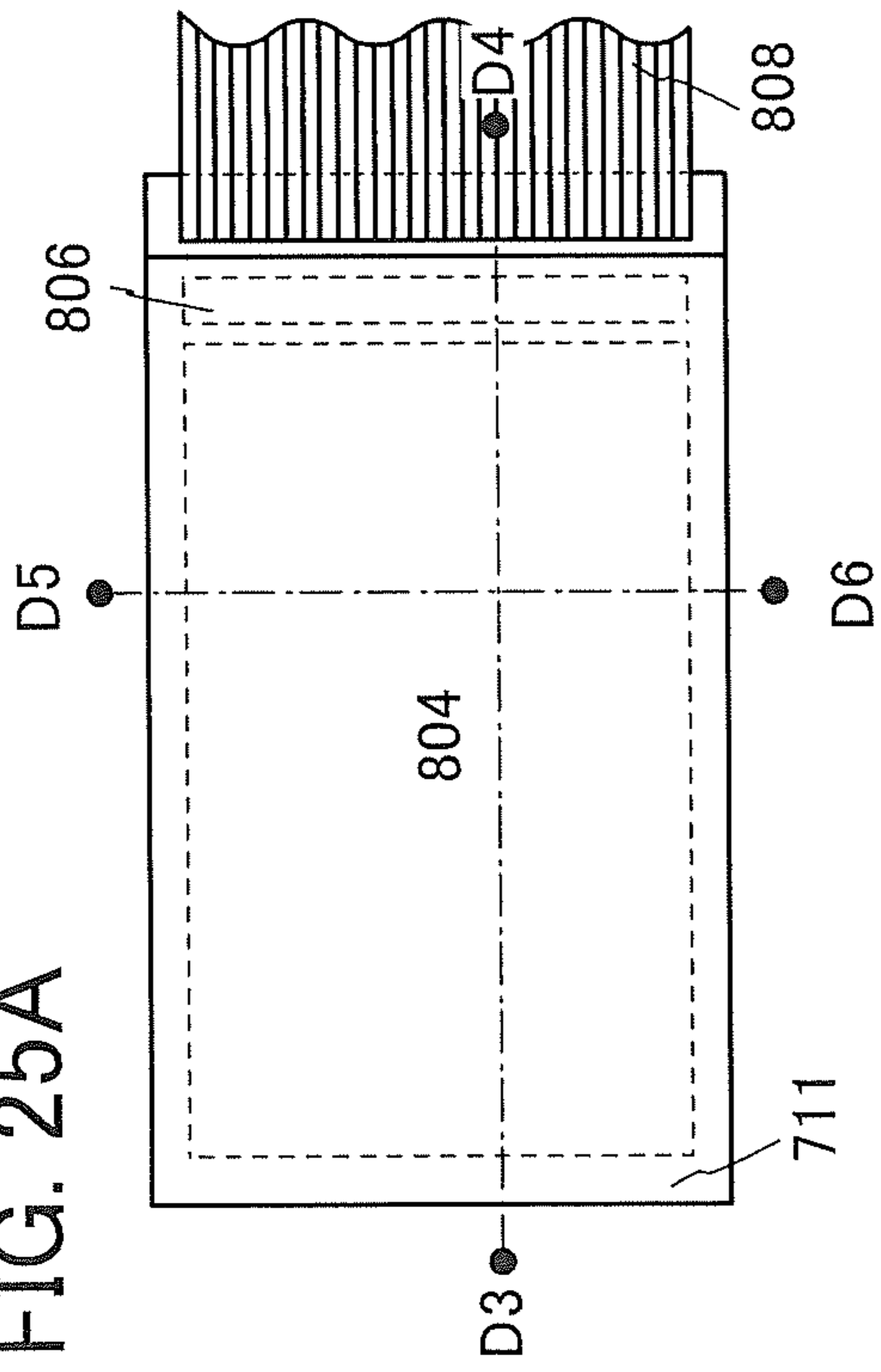
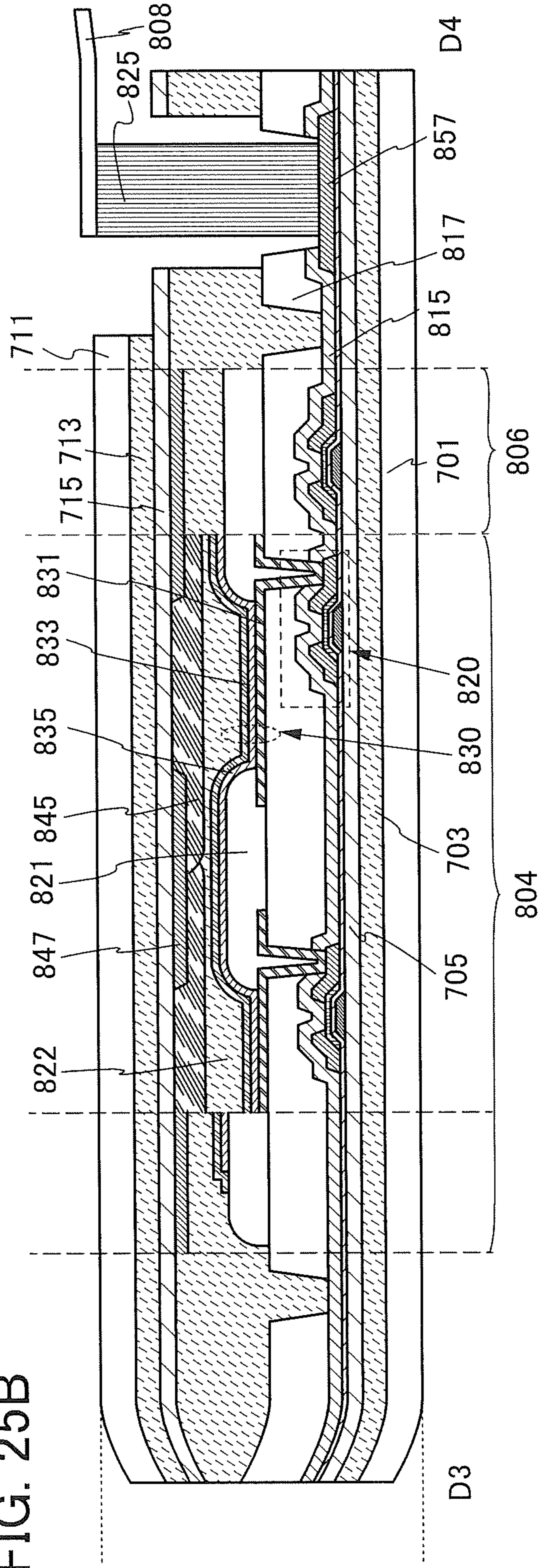


FIG. 25B



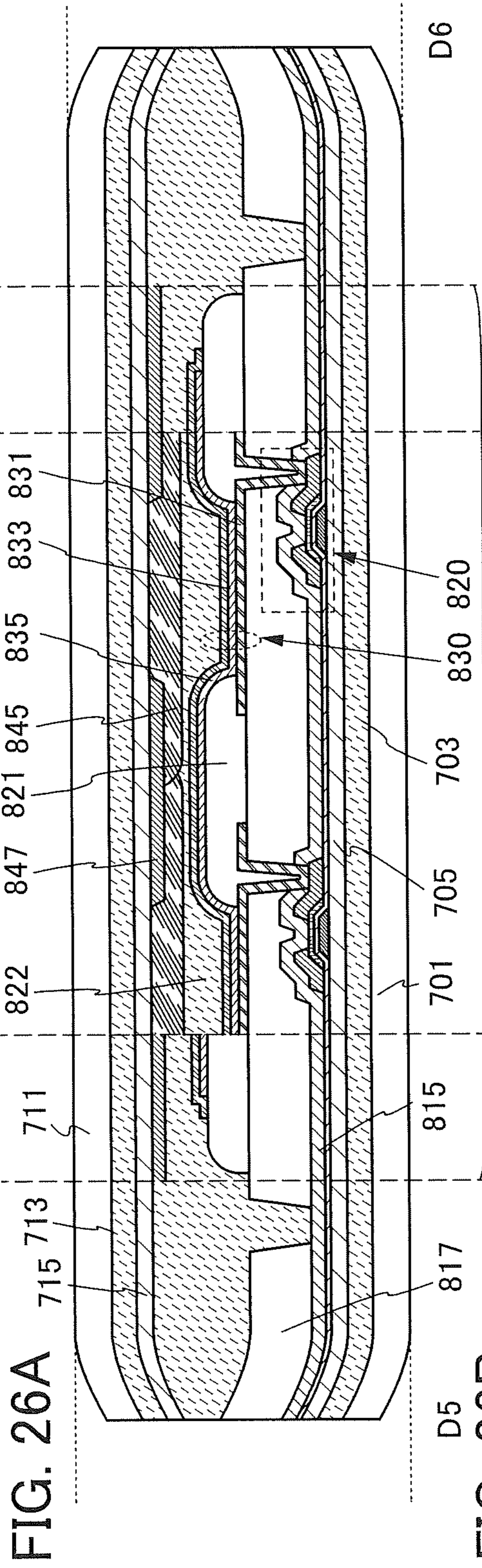


FIG. 26A

FIG. 26B

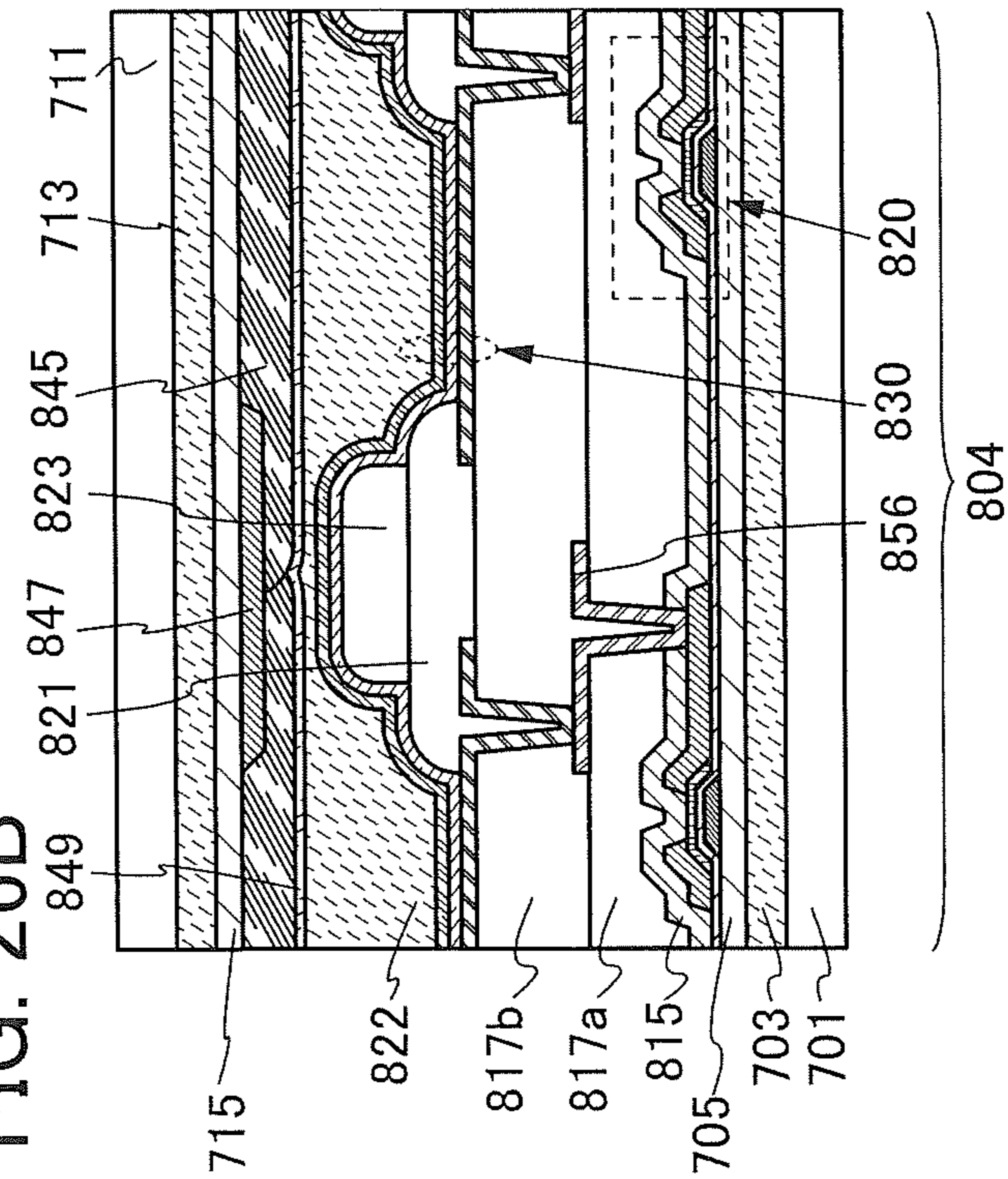


FIG. 26C

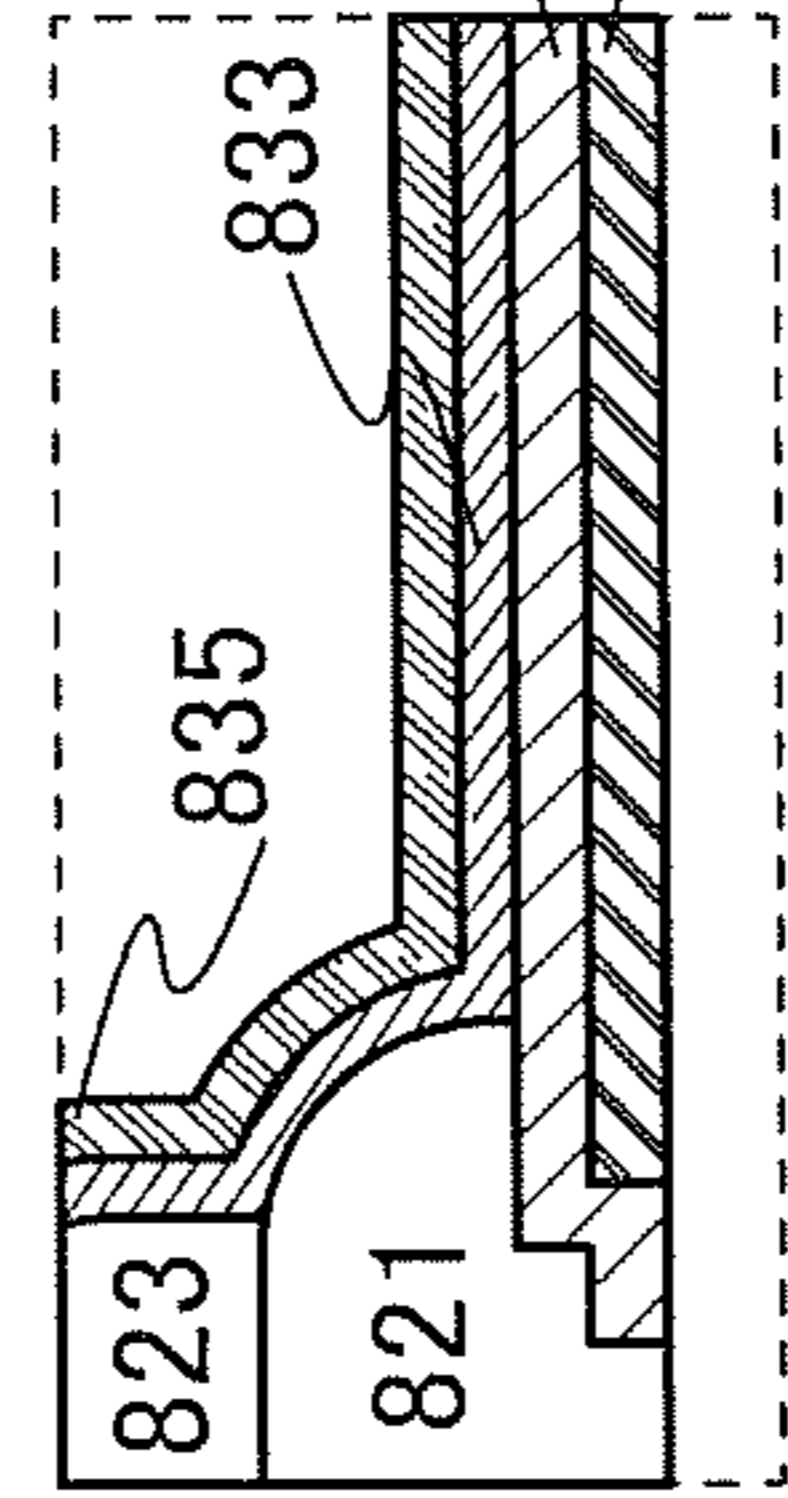
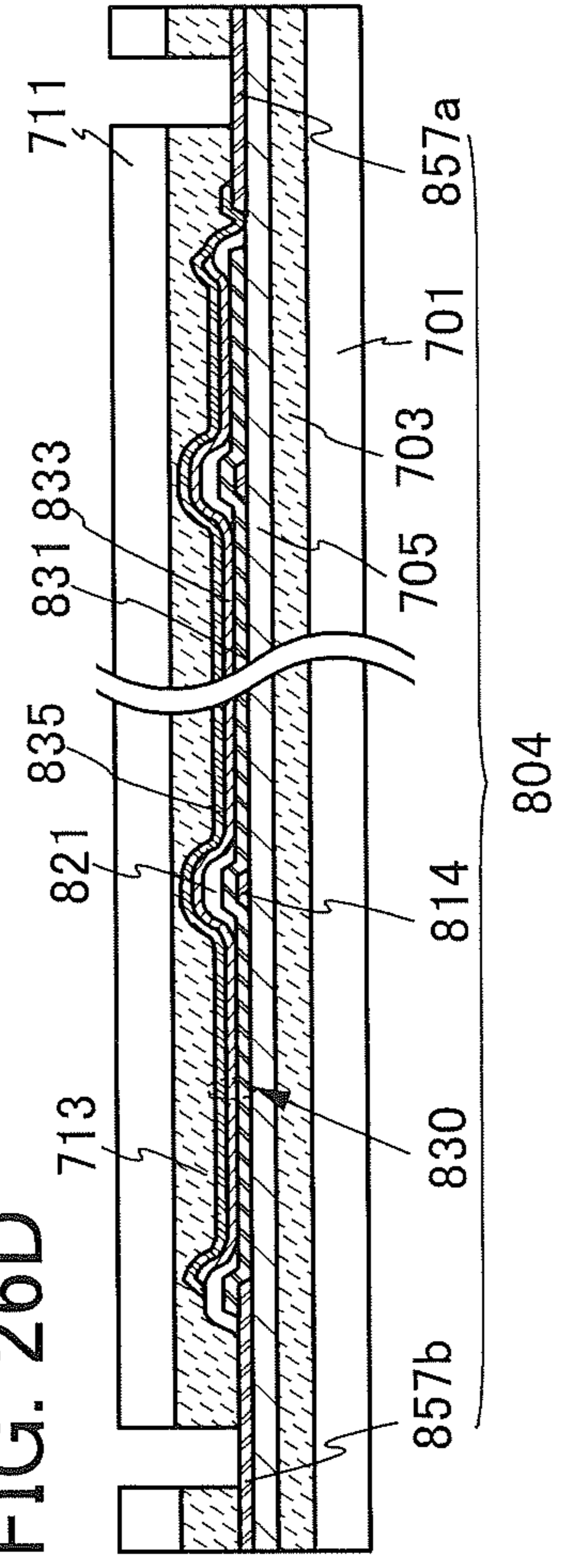


FIG. 26D



D6

D5

804

804

804

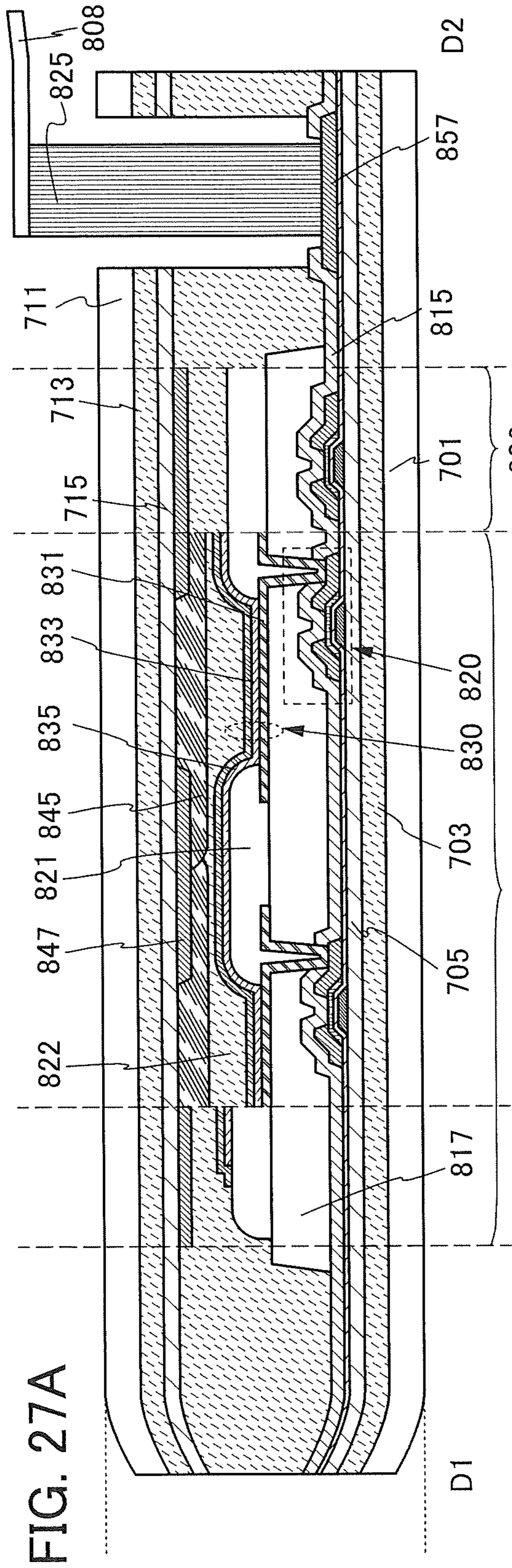


FIG. 27A

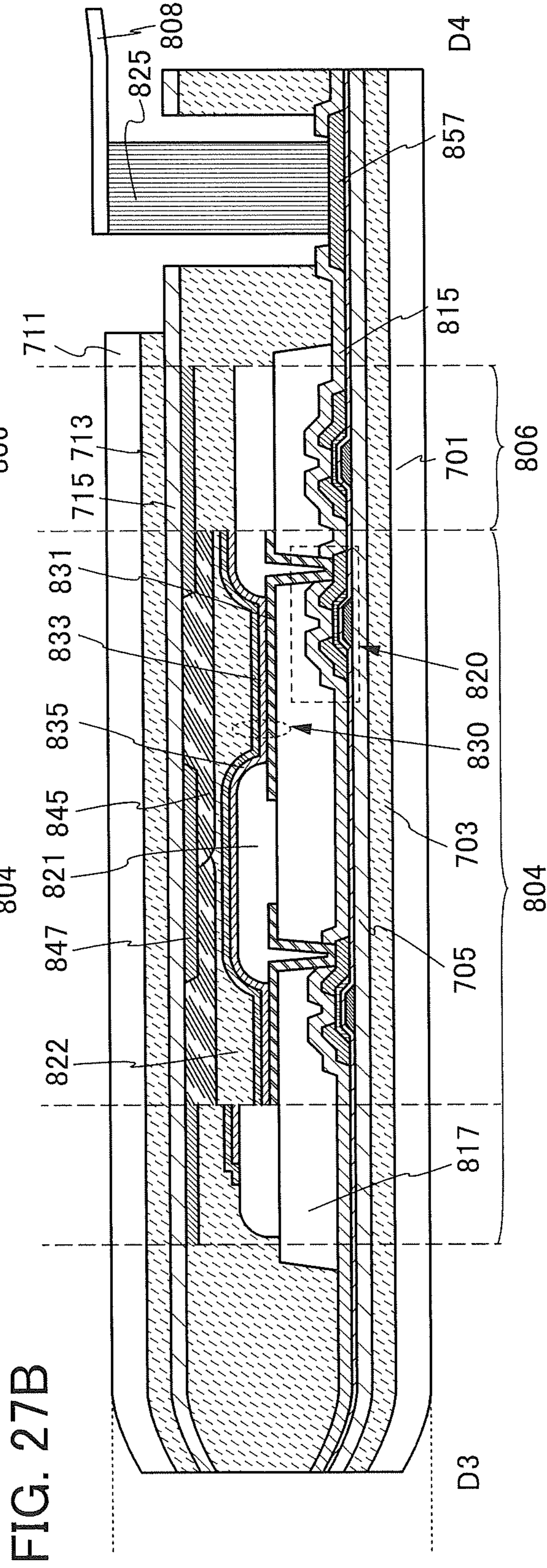
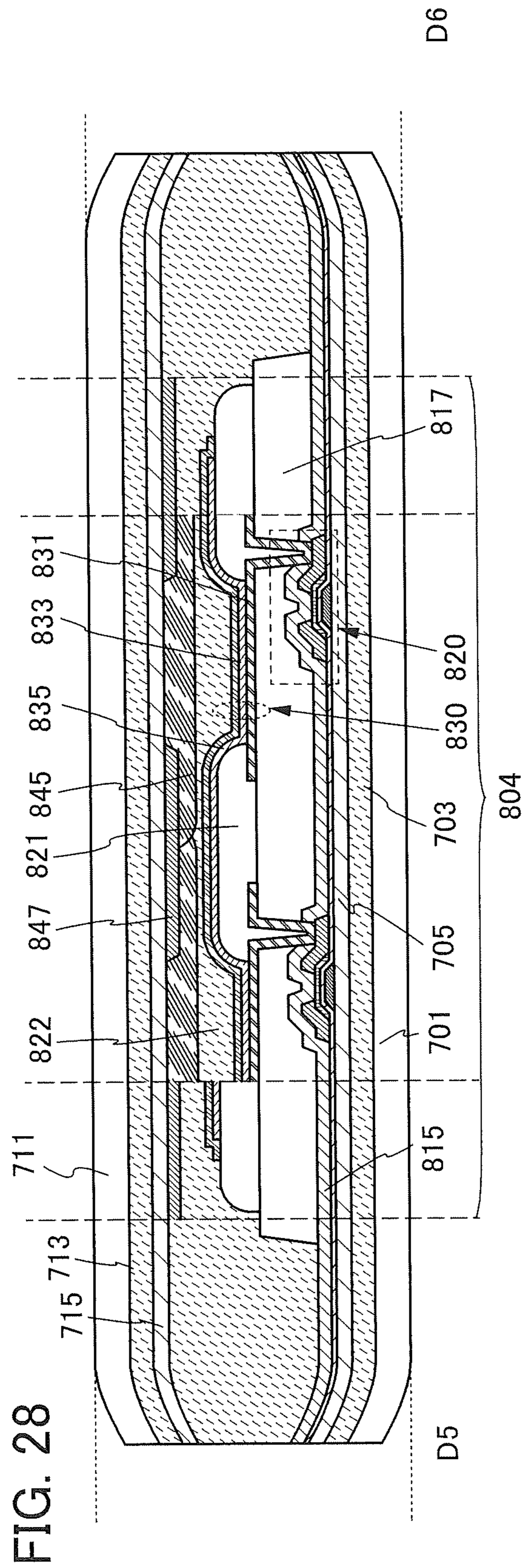
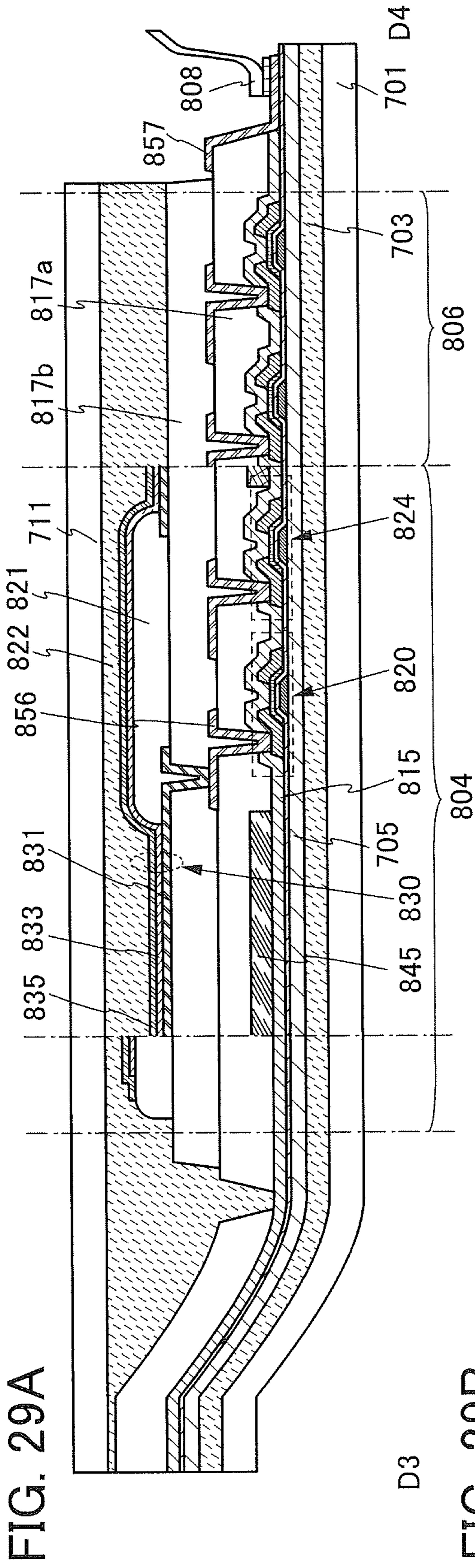
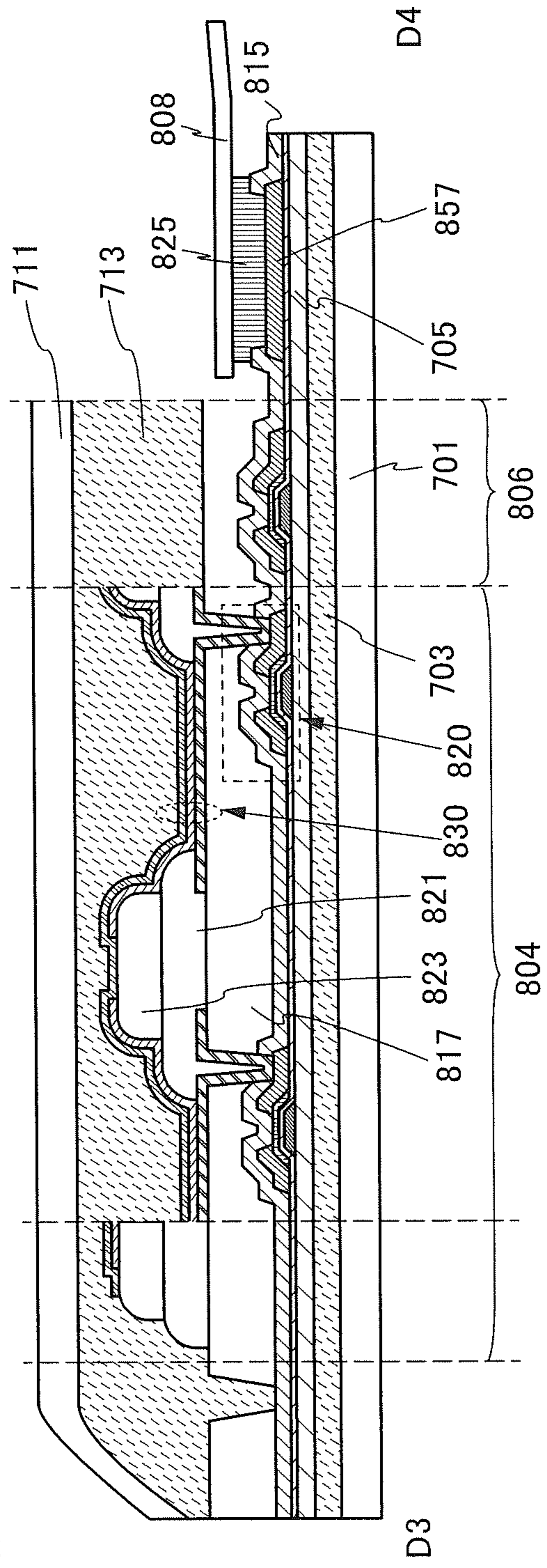


FIG. 27B

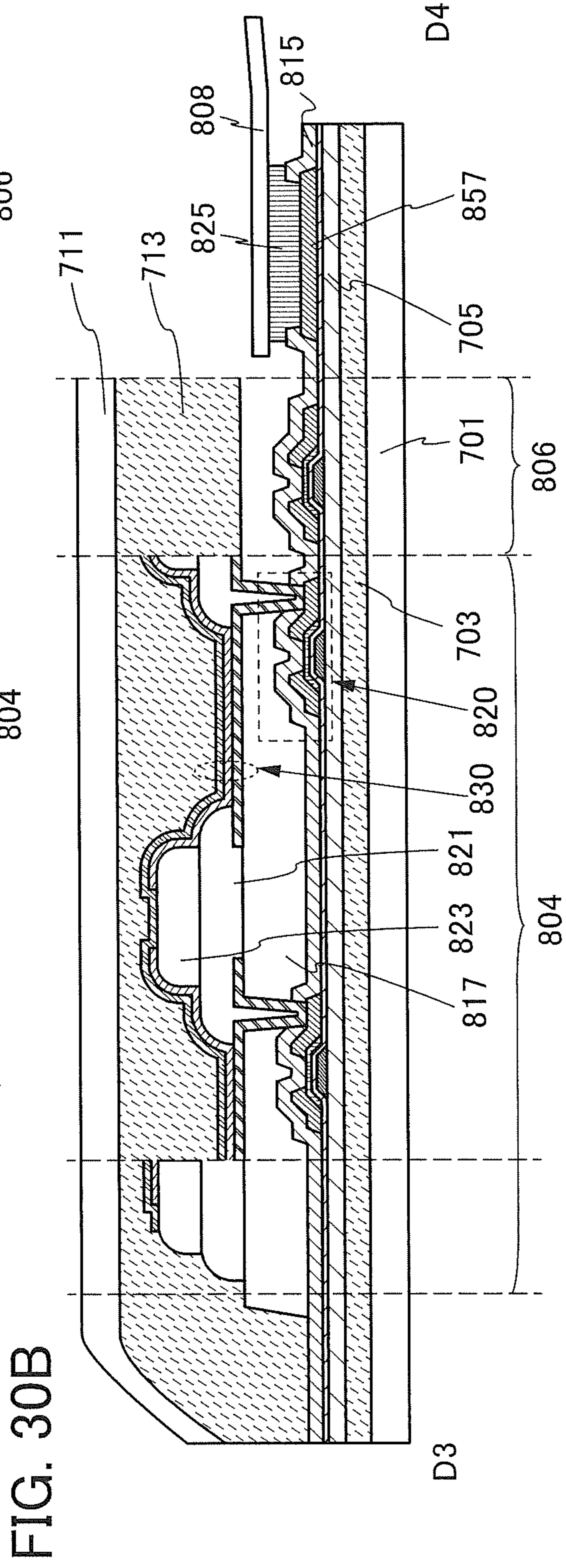
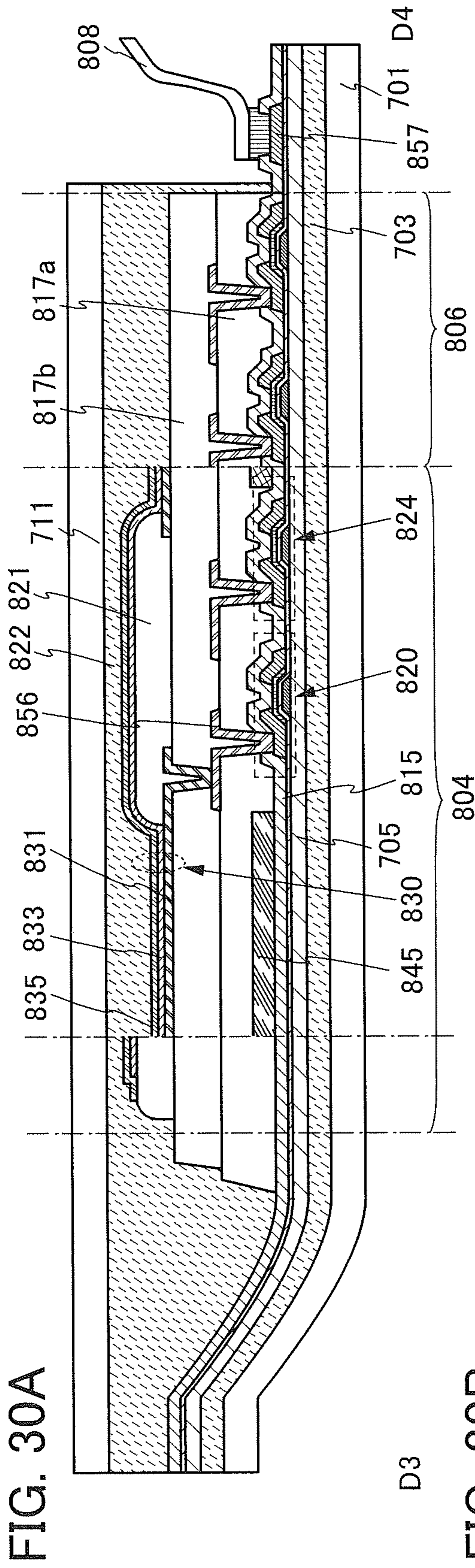


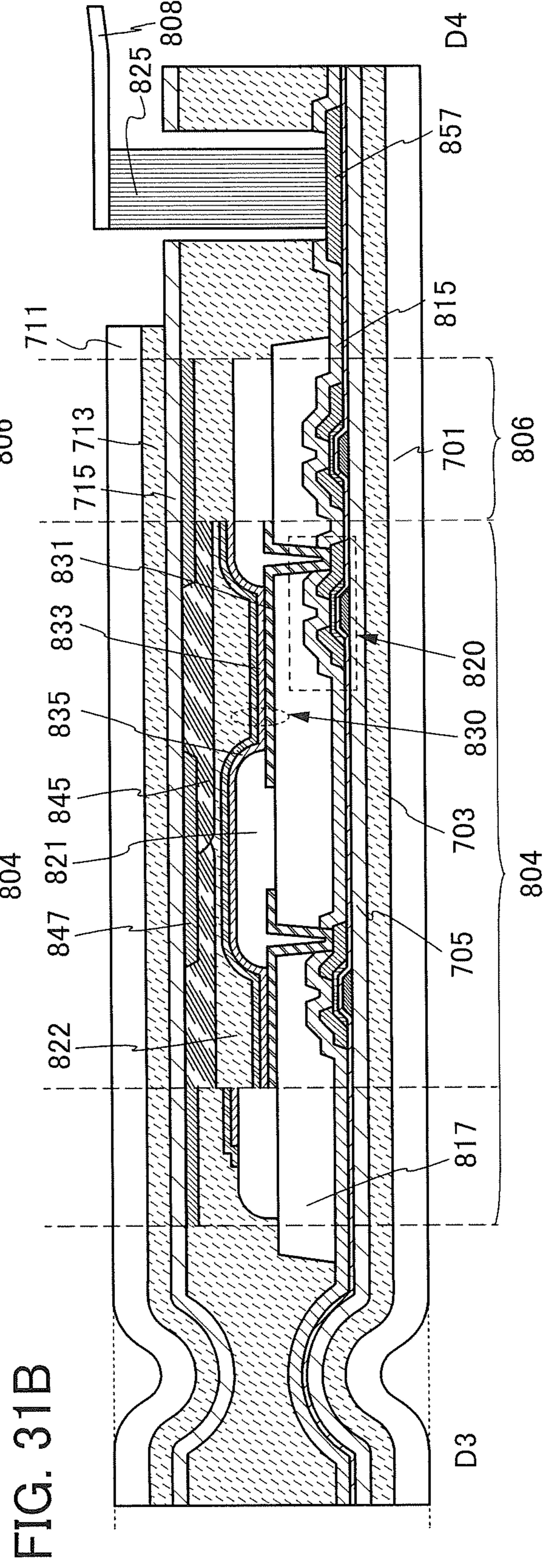
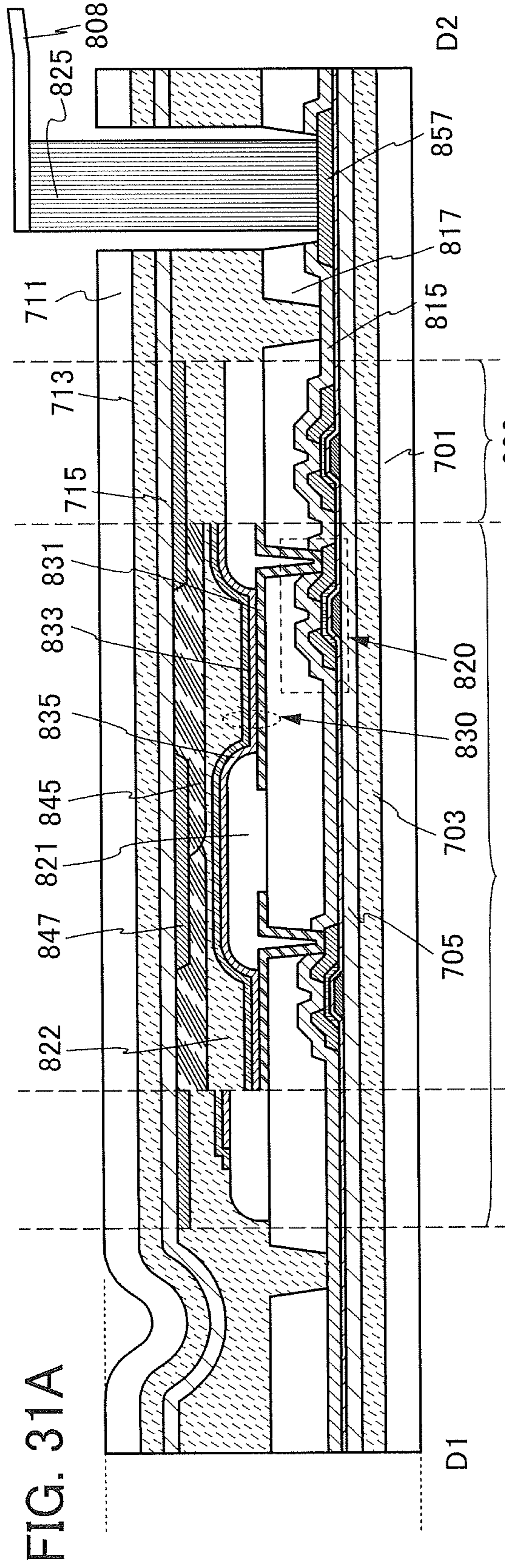


**FIG. 29B**









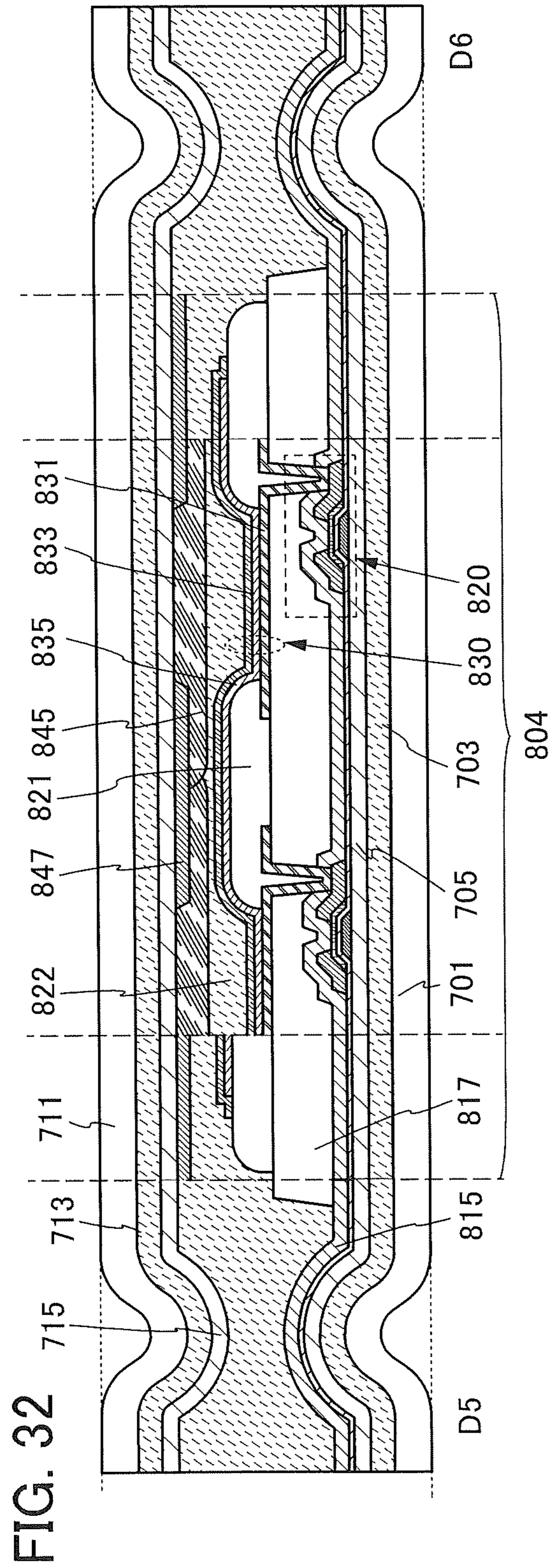


FIG. 33A

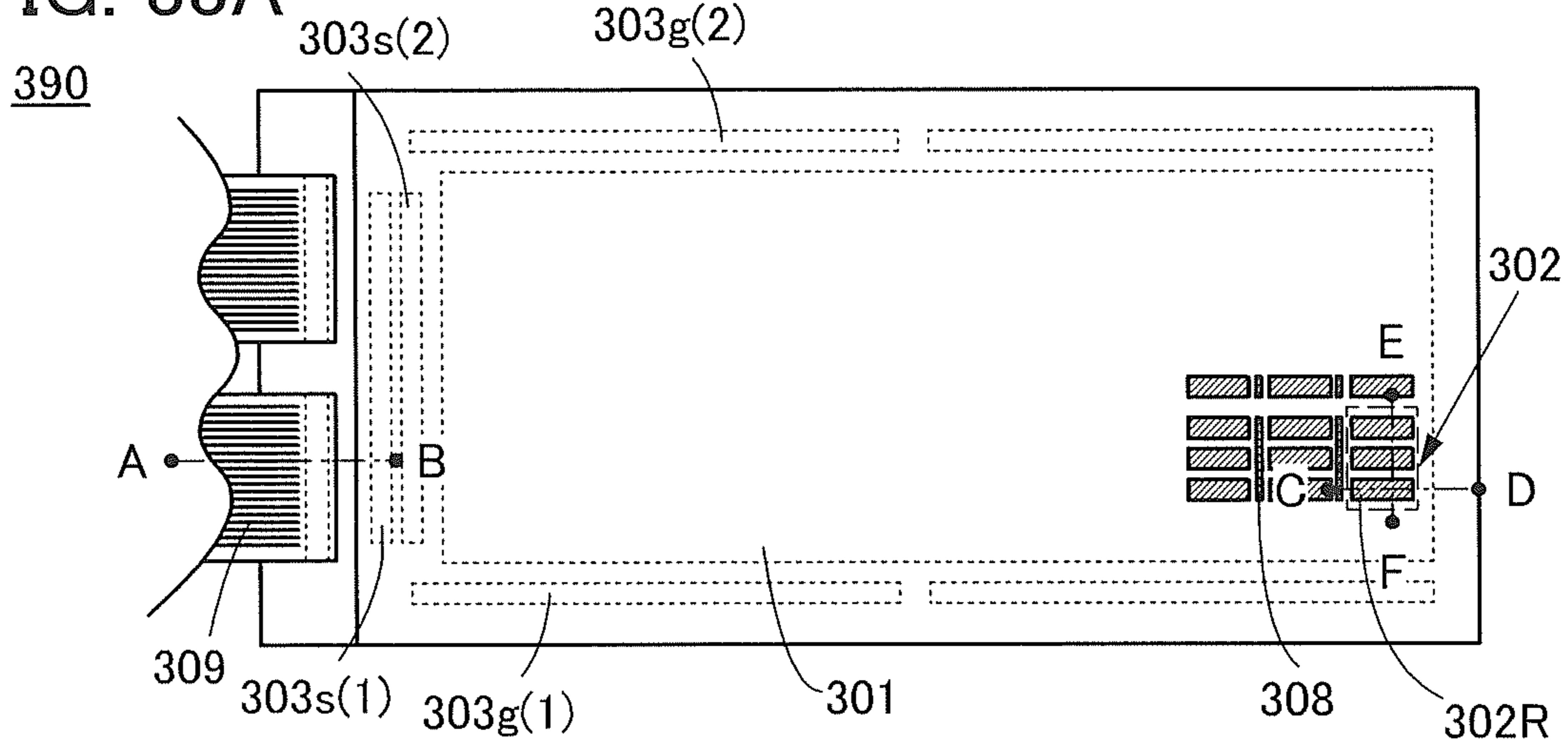


FIG. 33B

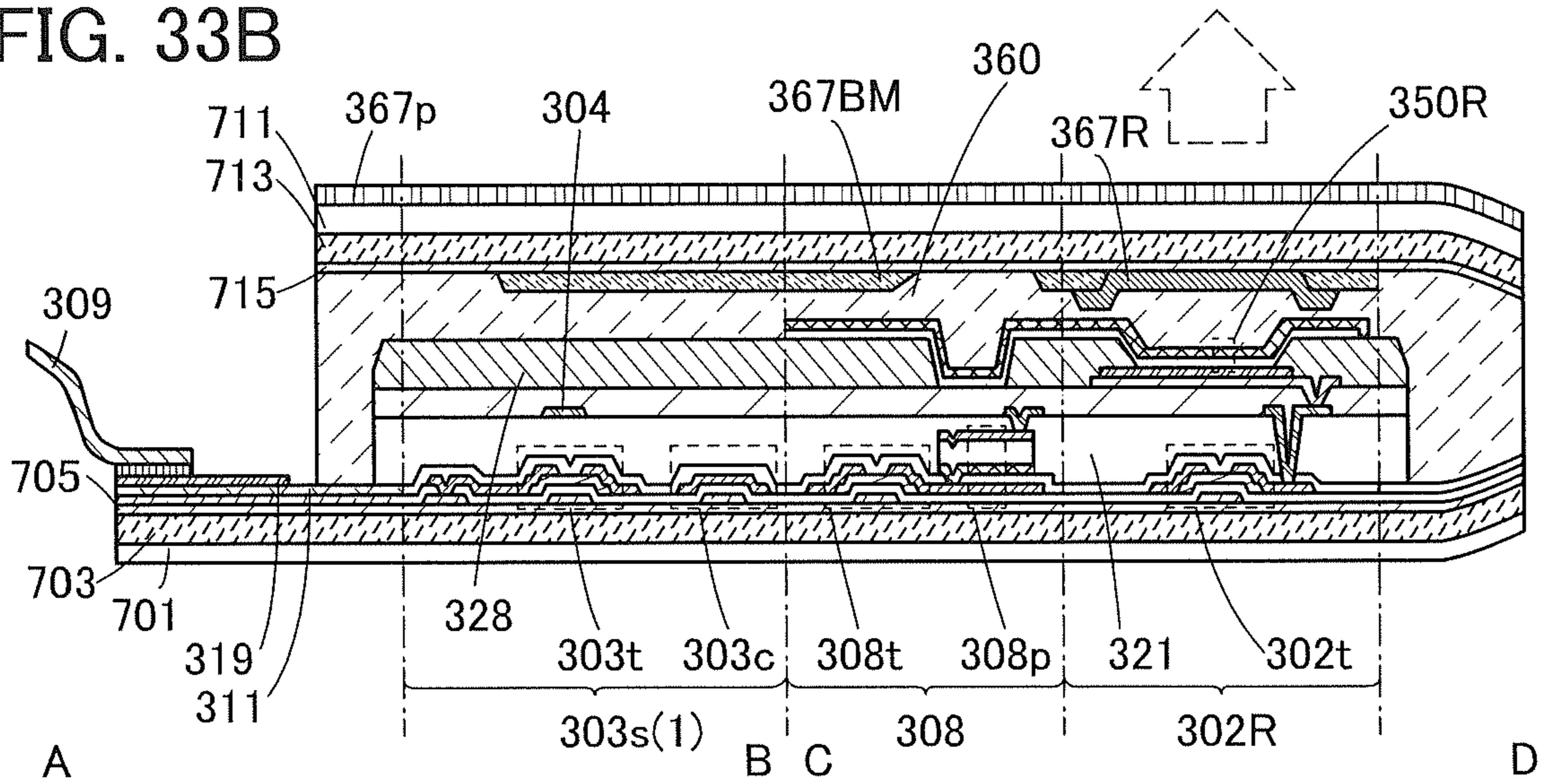


FIG. 33C

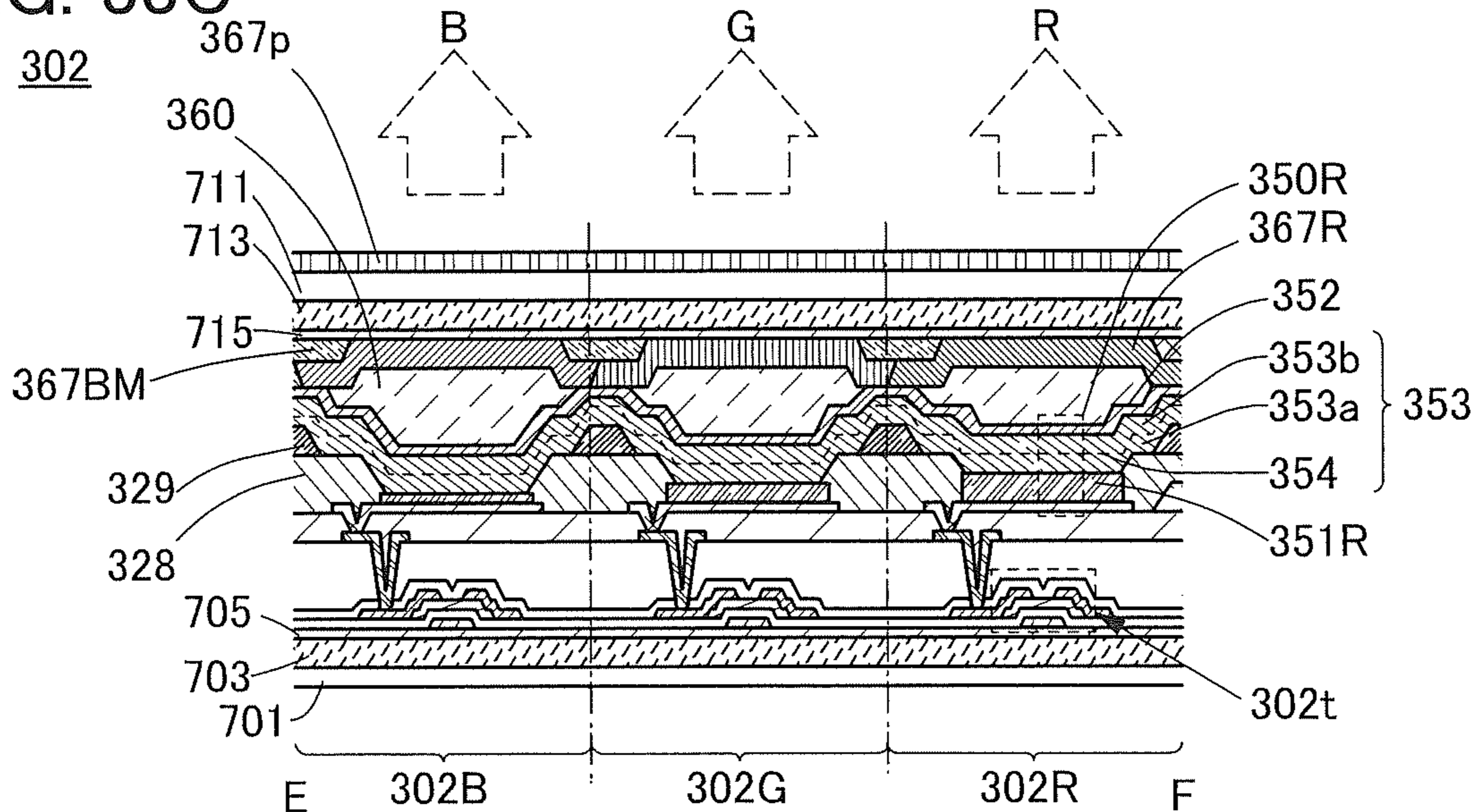


FIG. 34A

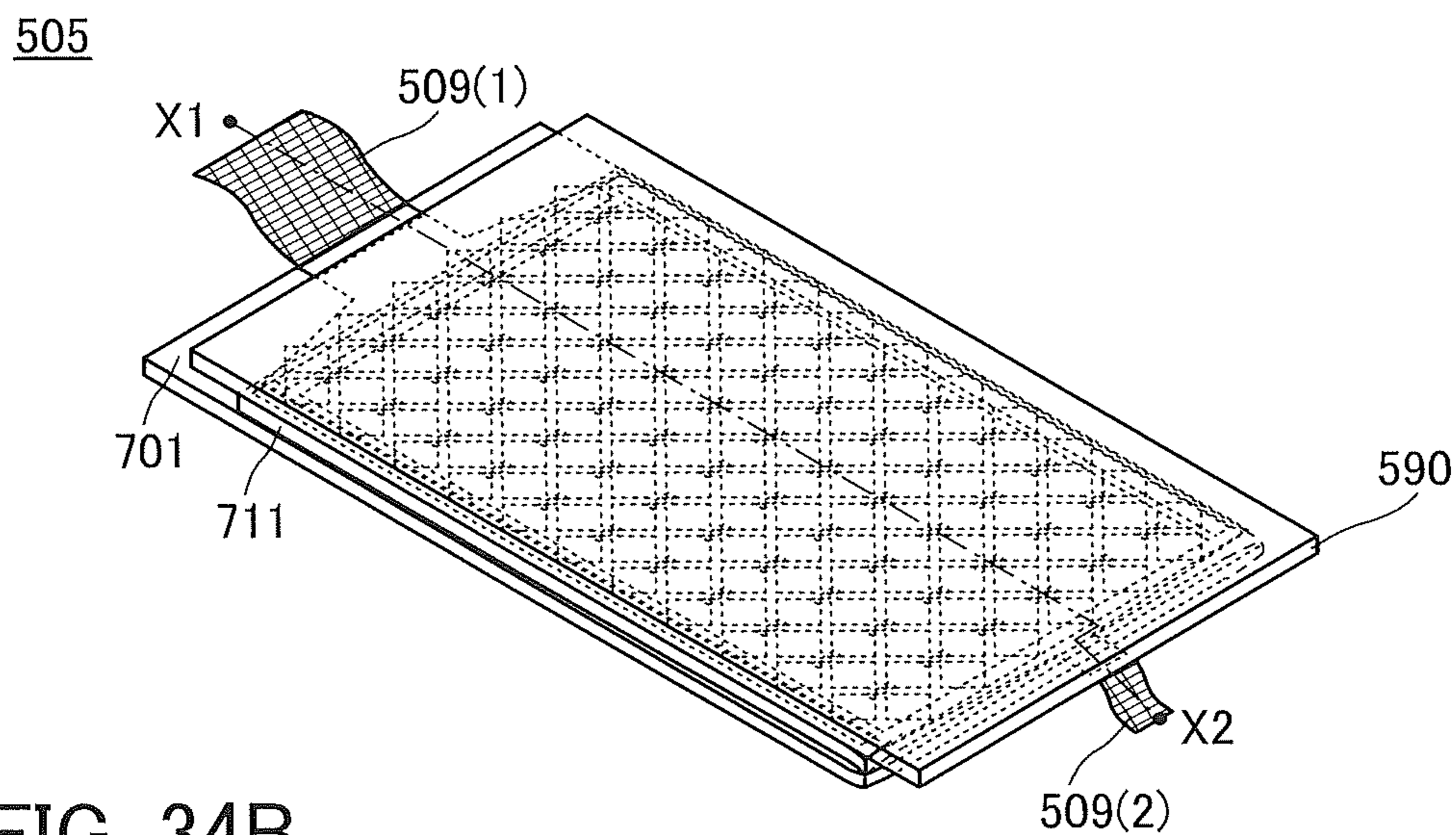


FIG. 34B

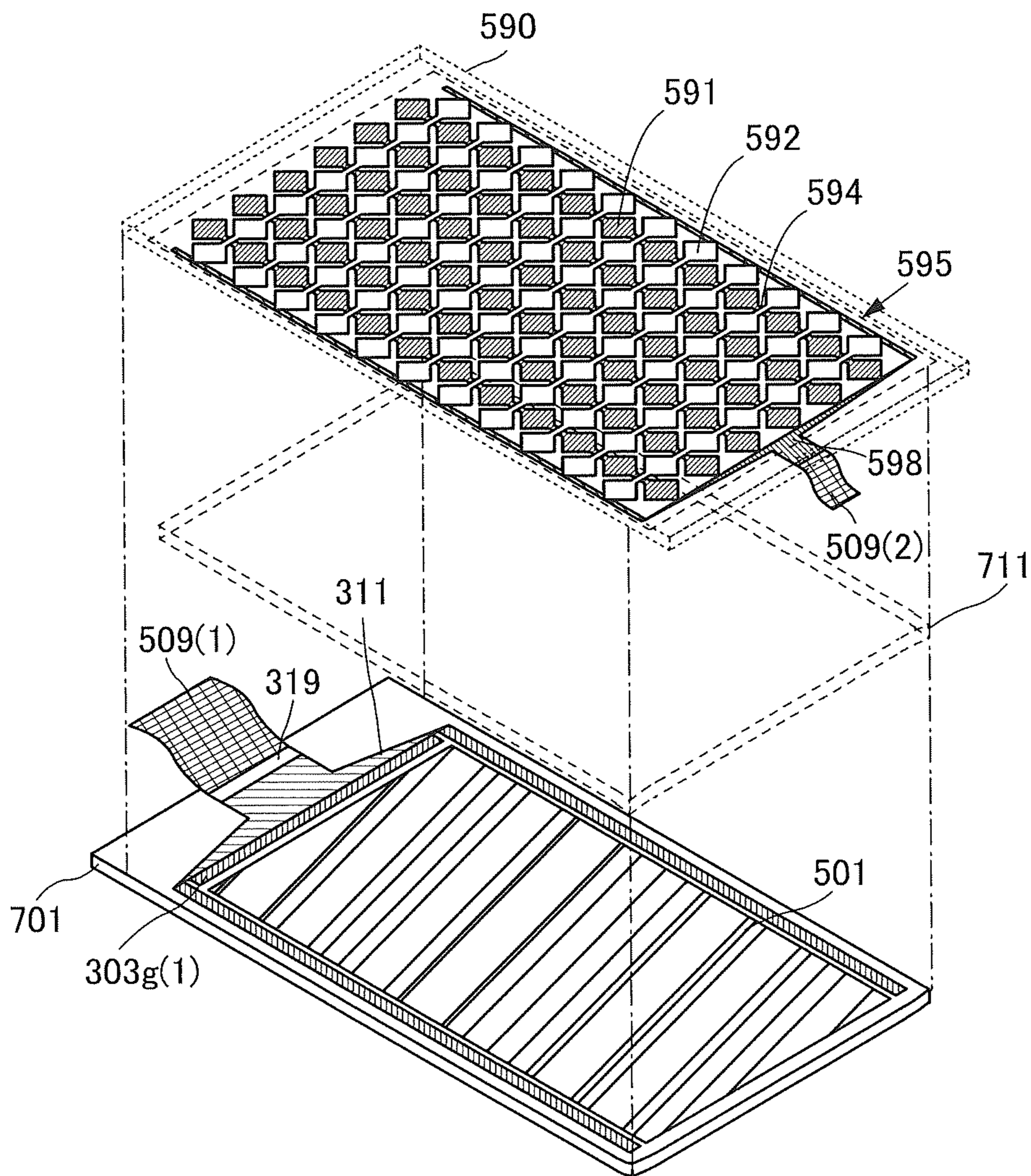


FIG. 35A

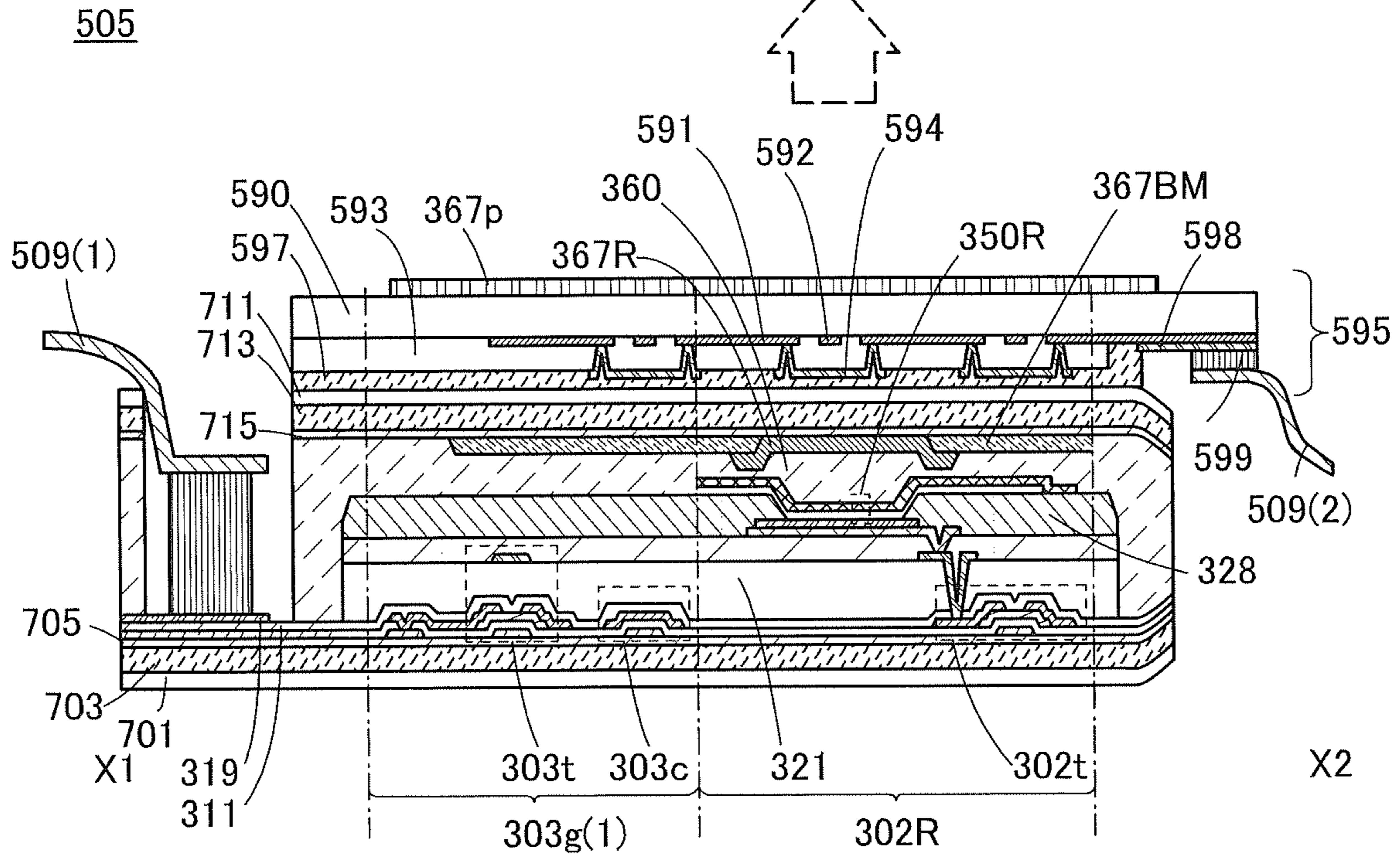


FIG. 35B

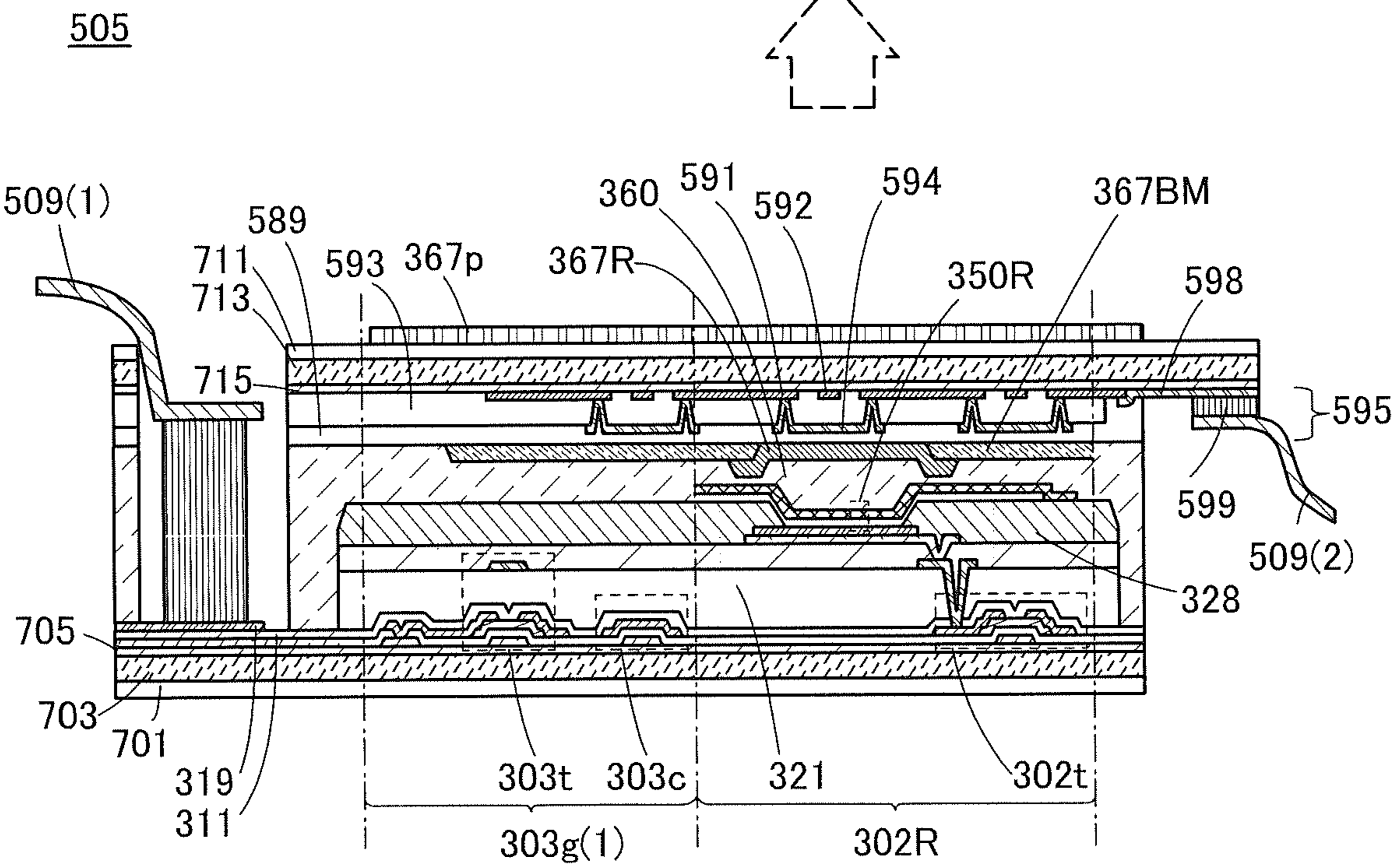


FIG. 36A

505B

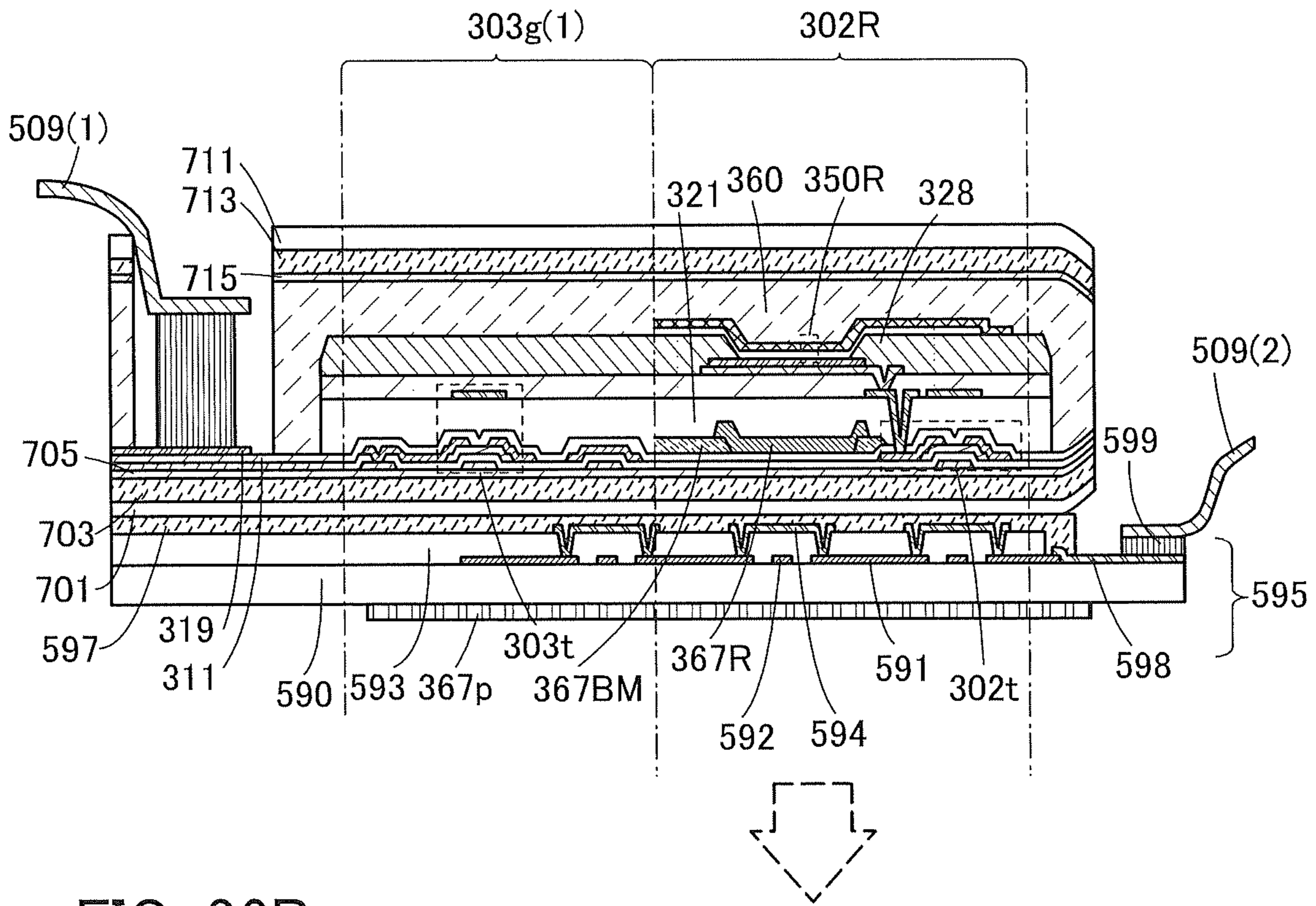


FIG. 36B

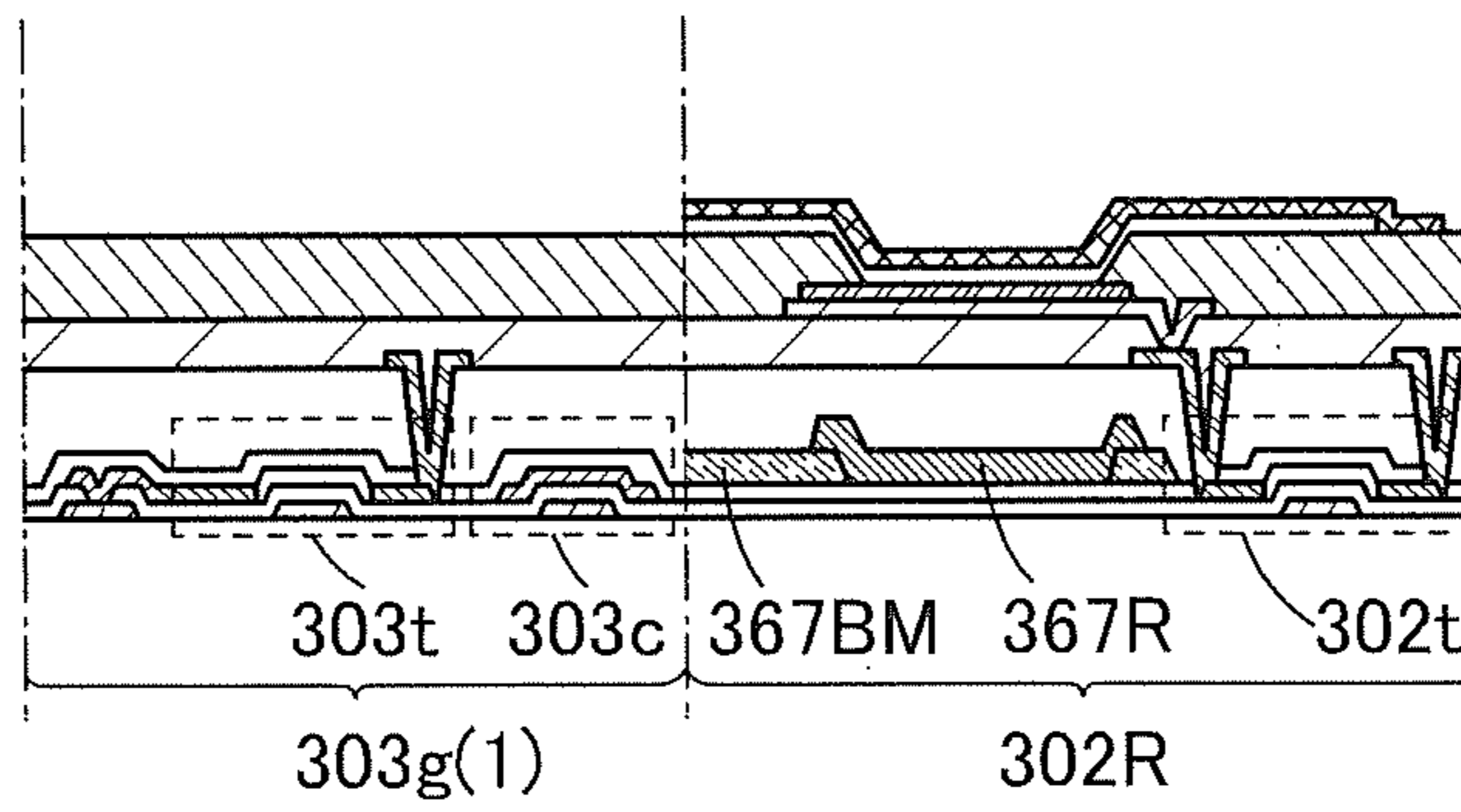


FIG. 36C

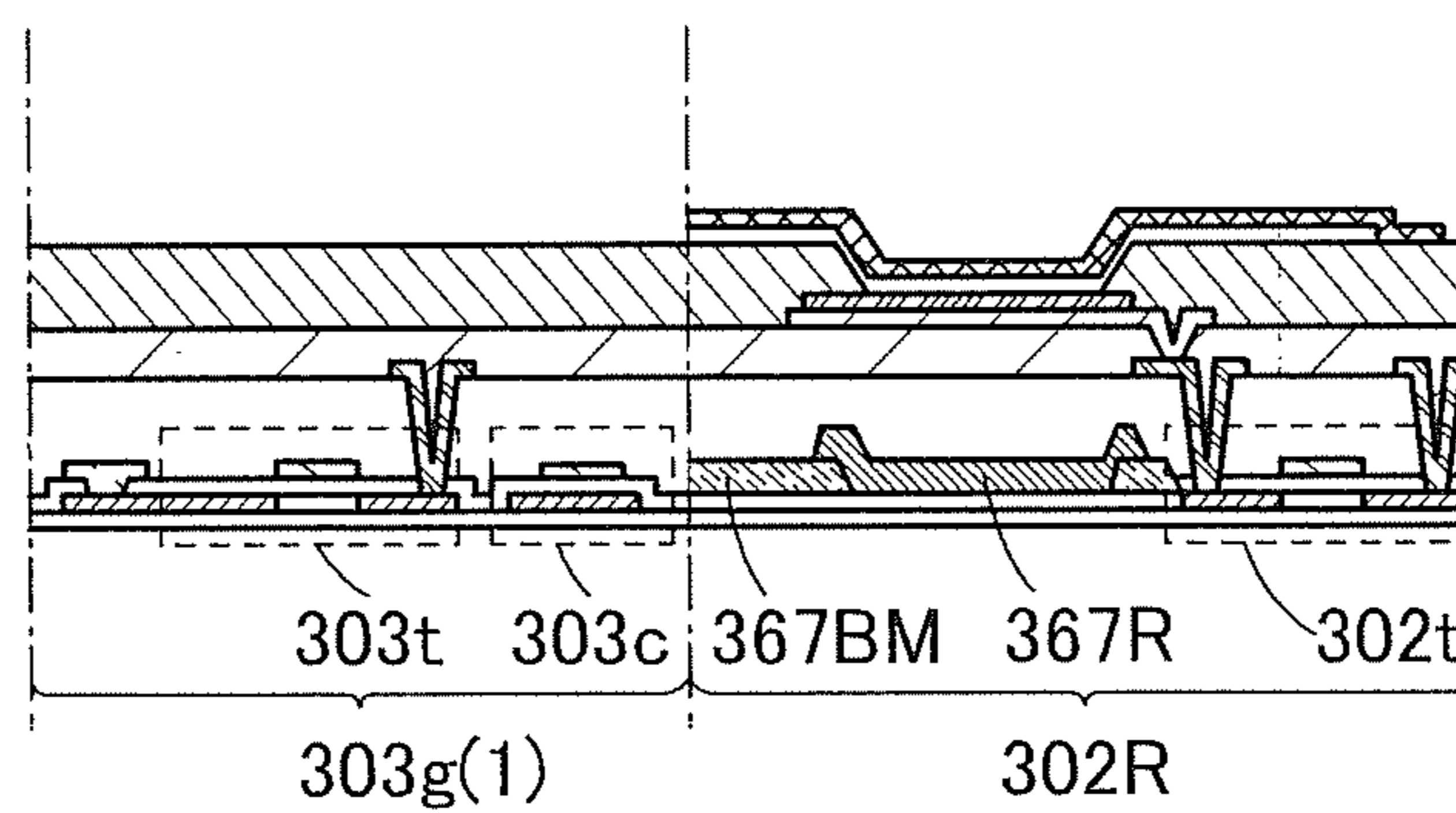


FIG. 37A

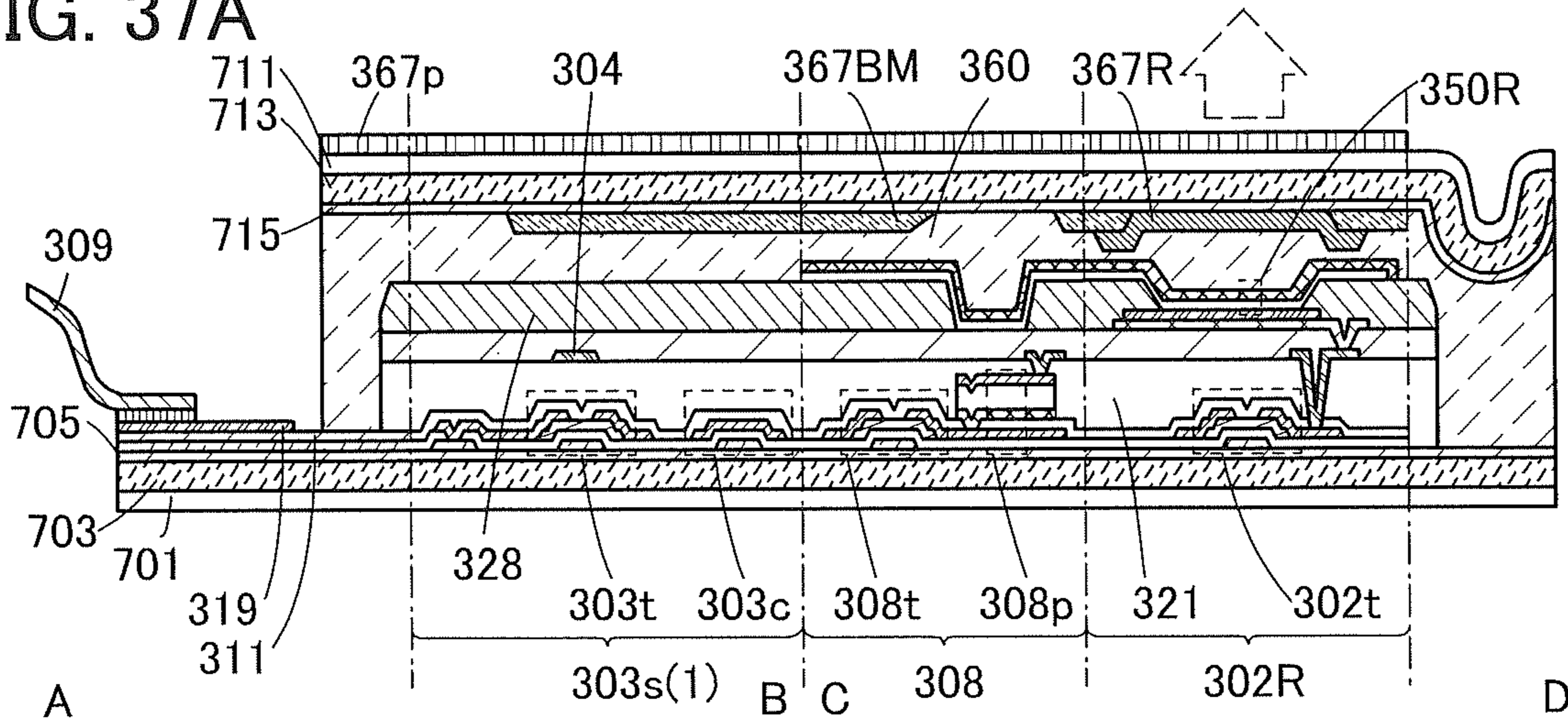


FIG. 37B

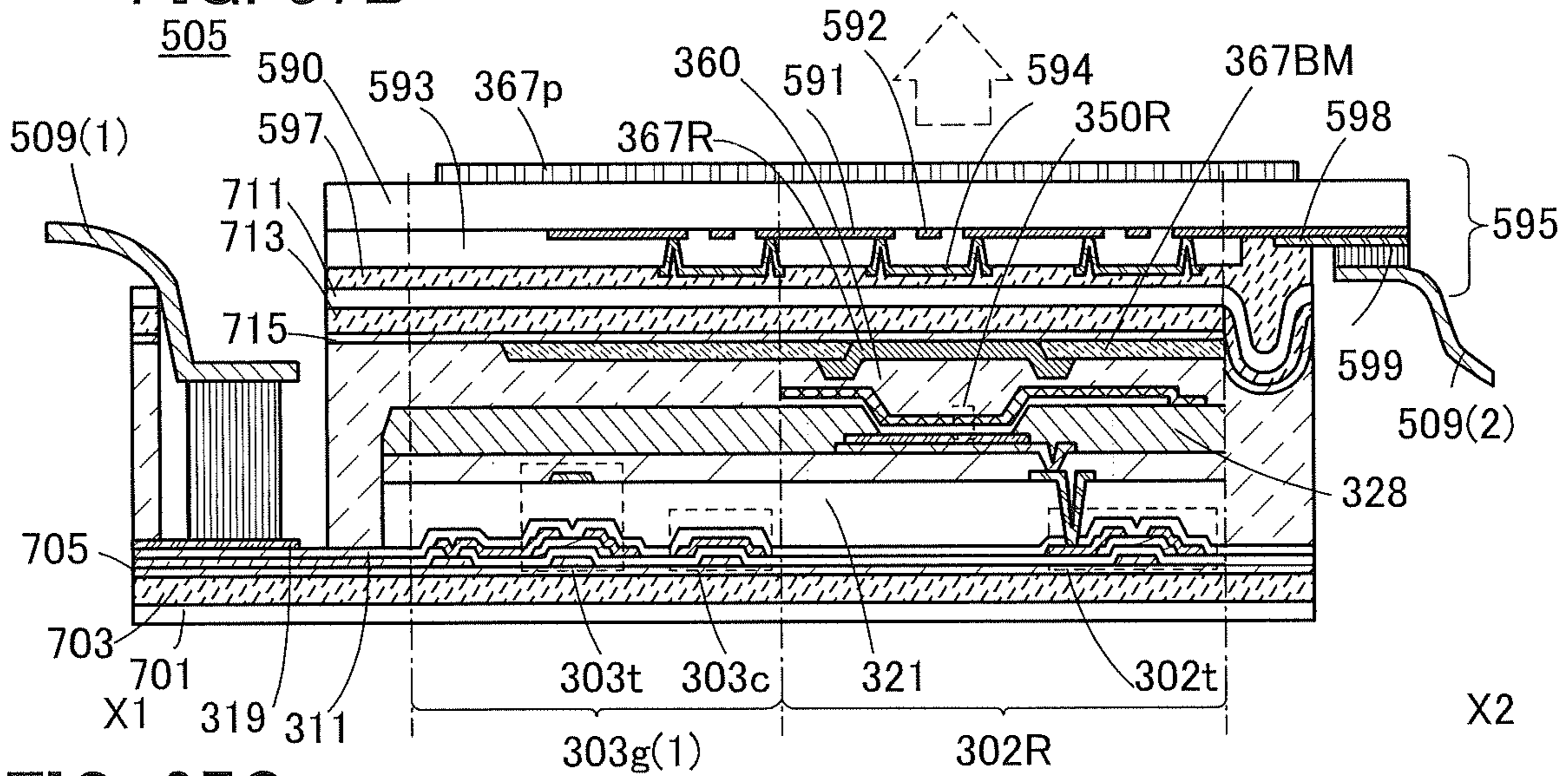


FIG. 37C

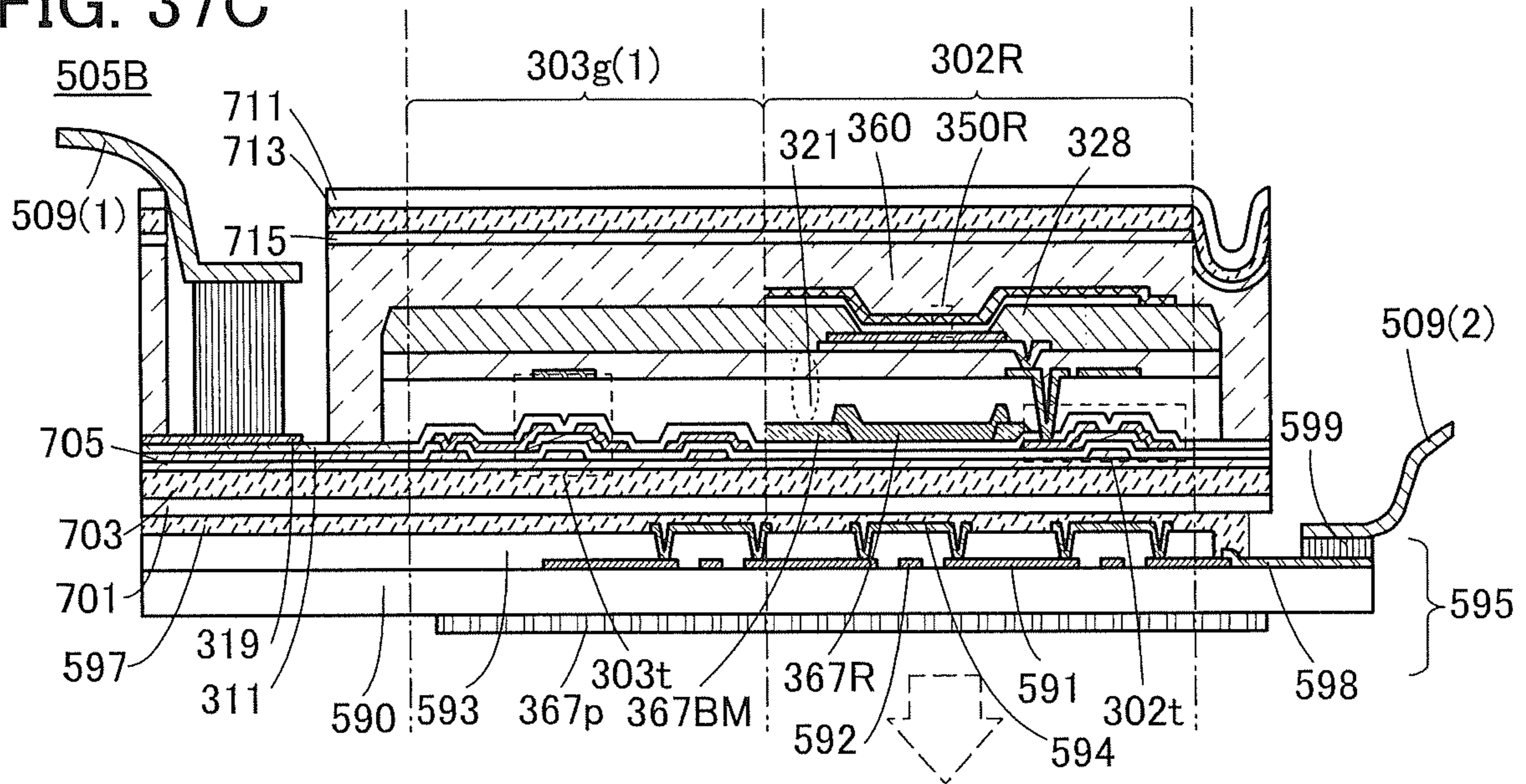




FIG. 38A

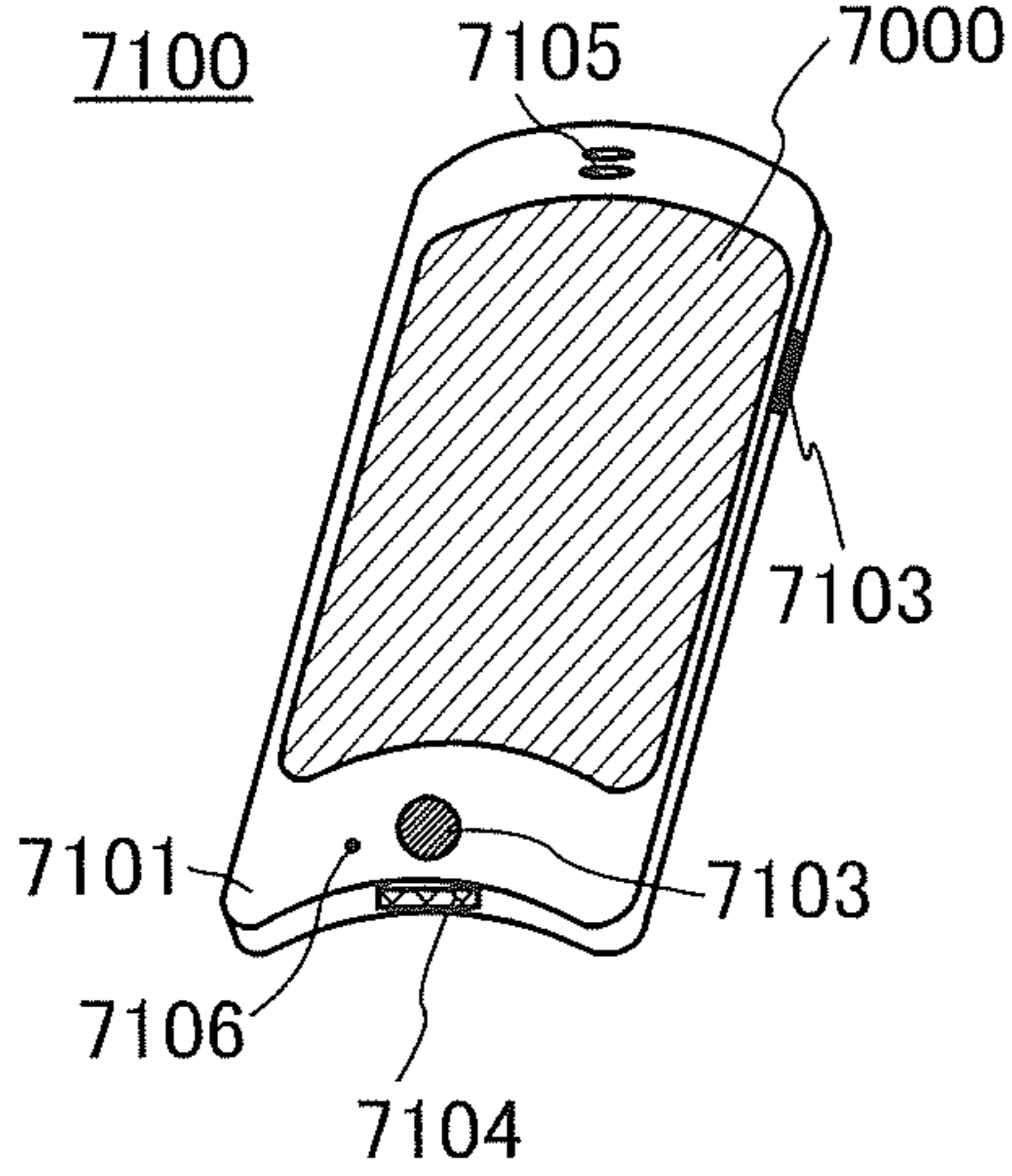


FIG. 38B

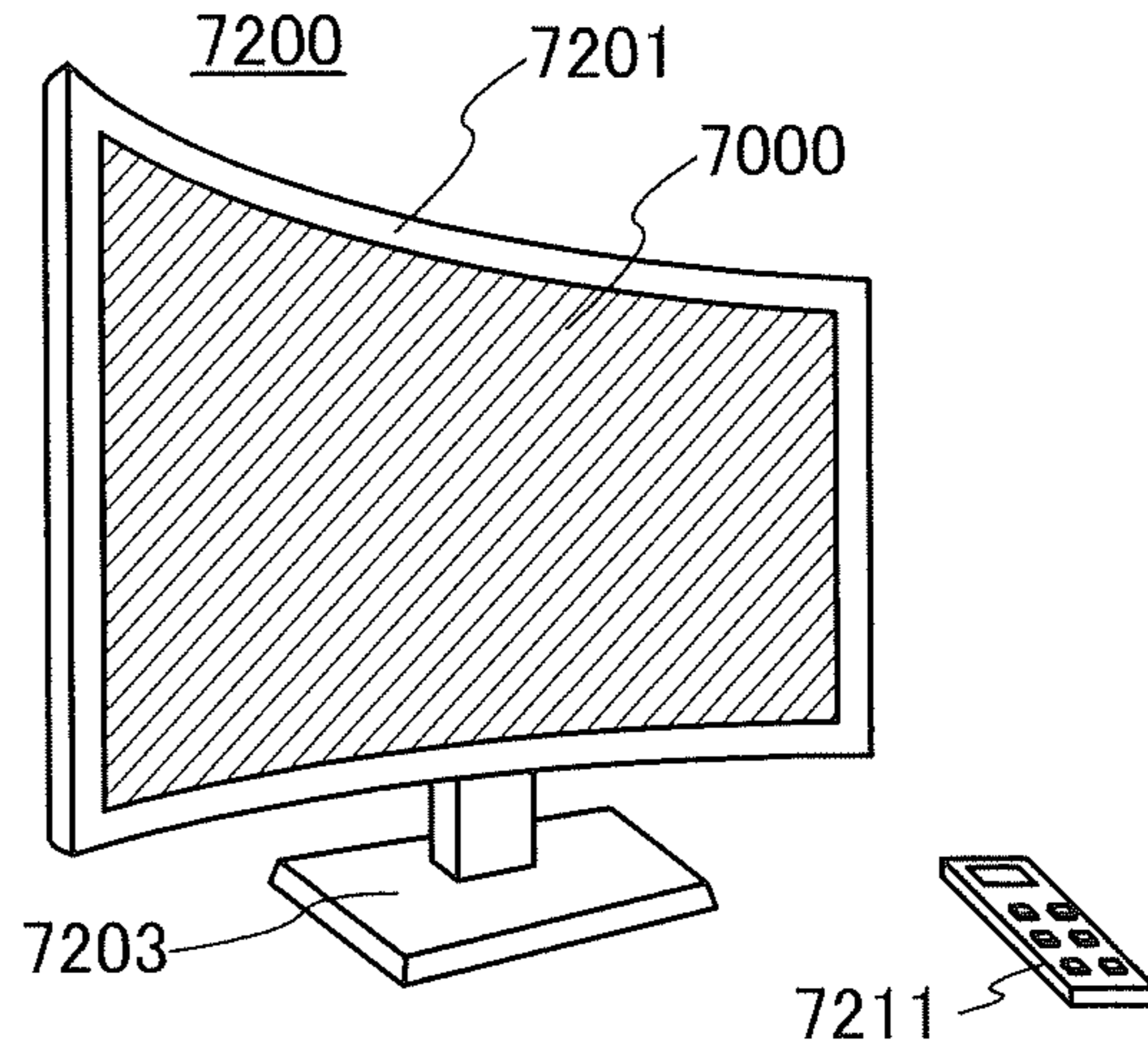


FIG. 38C1

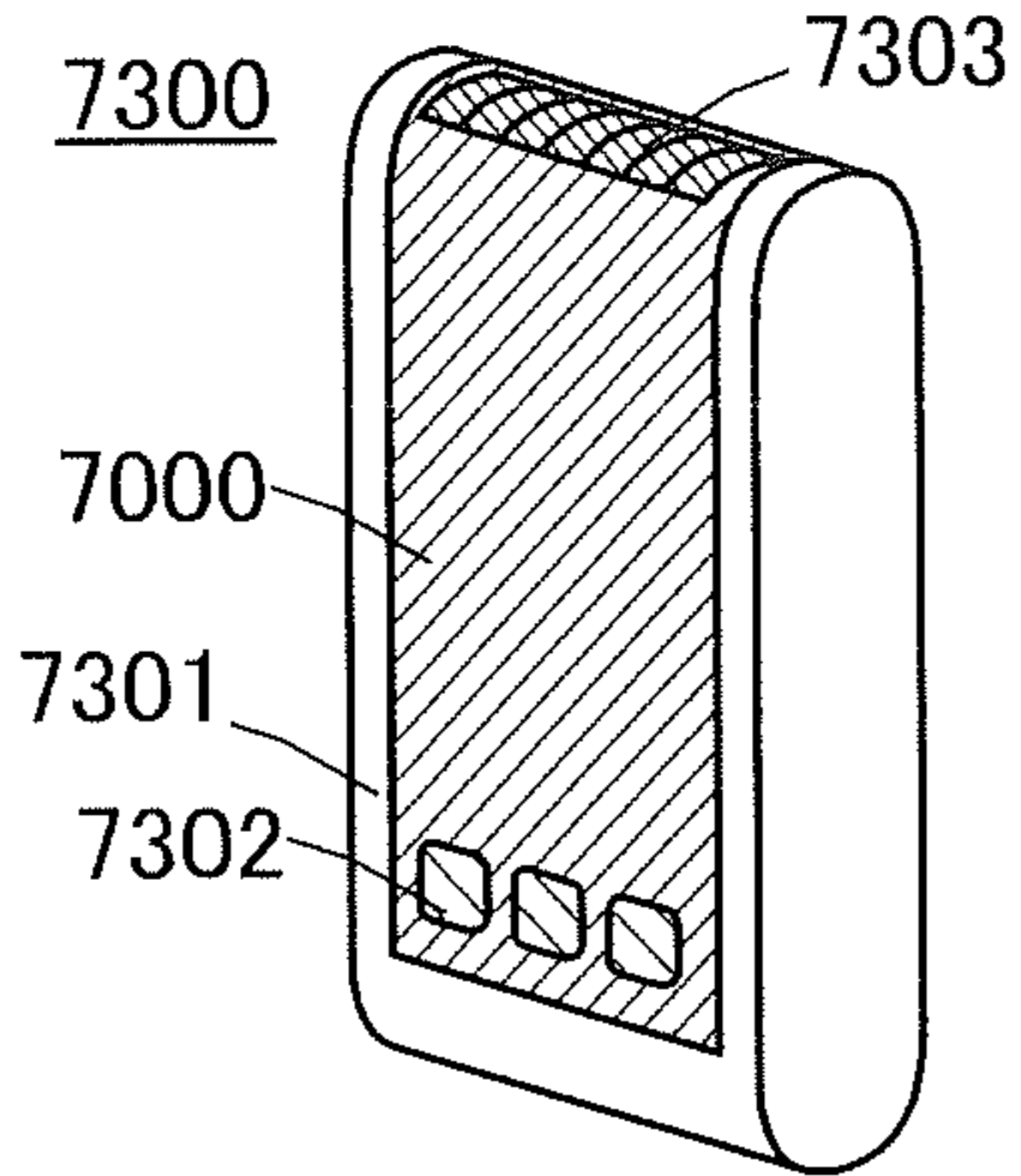


FIG. 38D

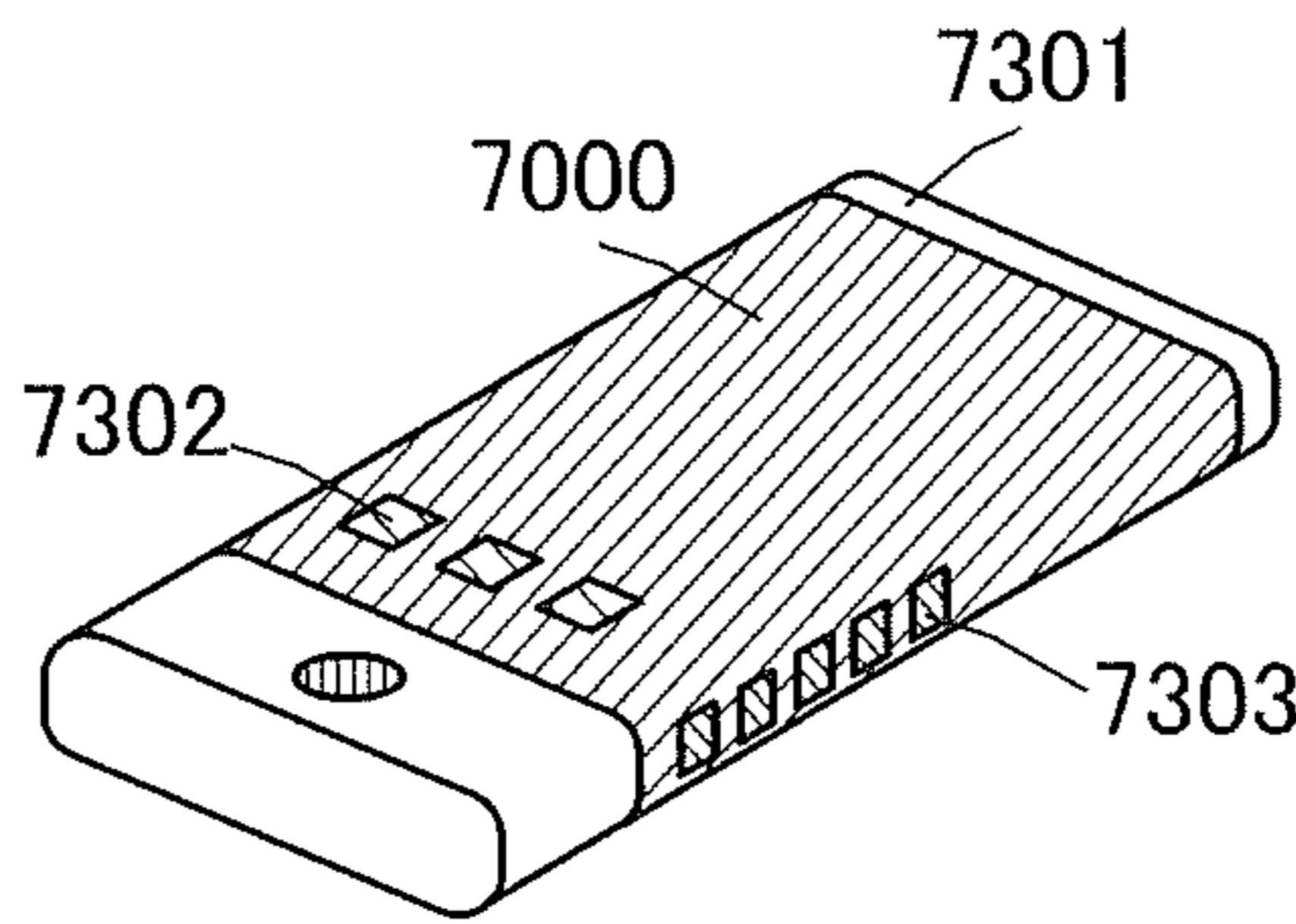


FIG. 38E

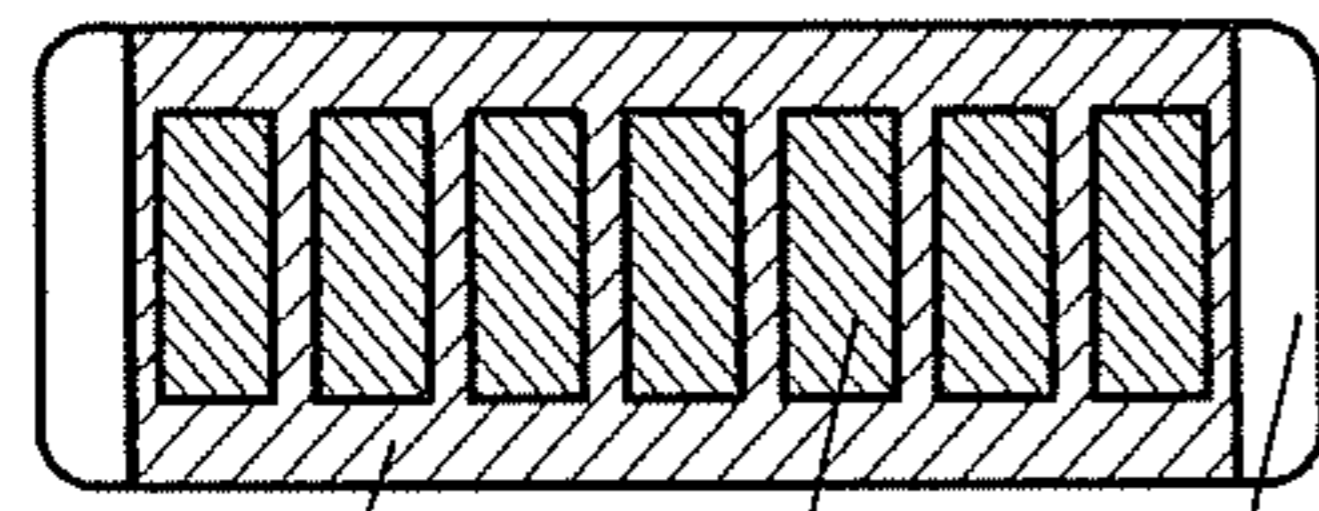
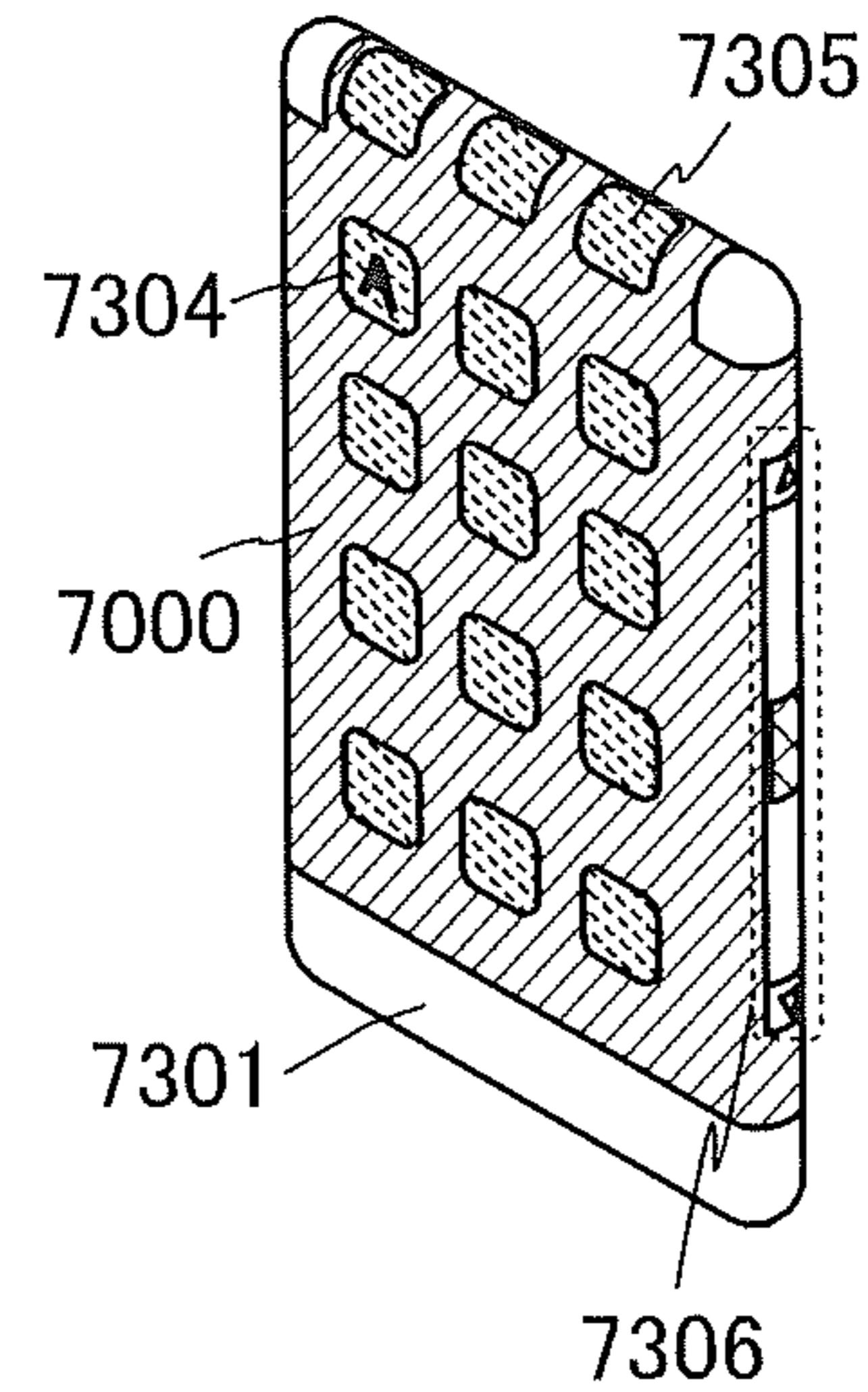


FIG. 38C2

FIG. 38F

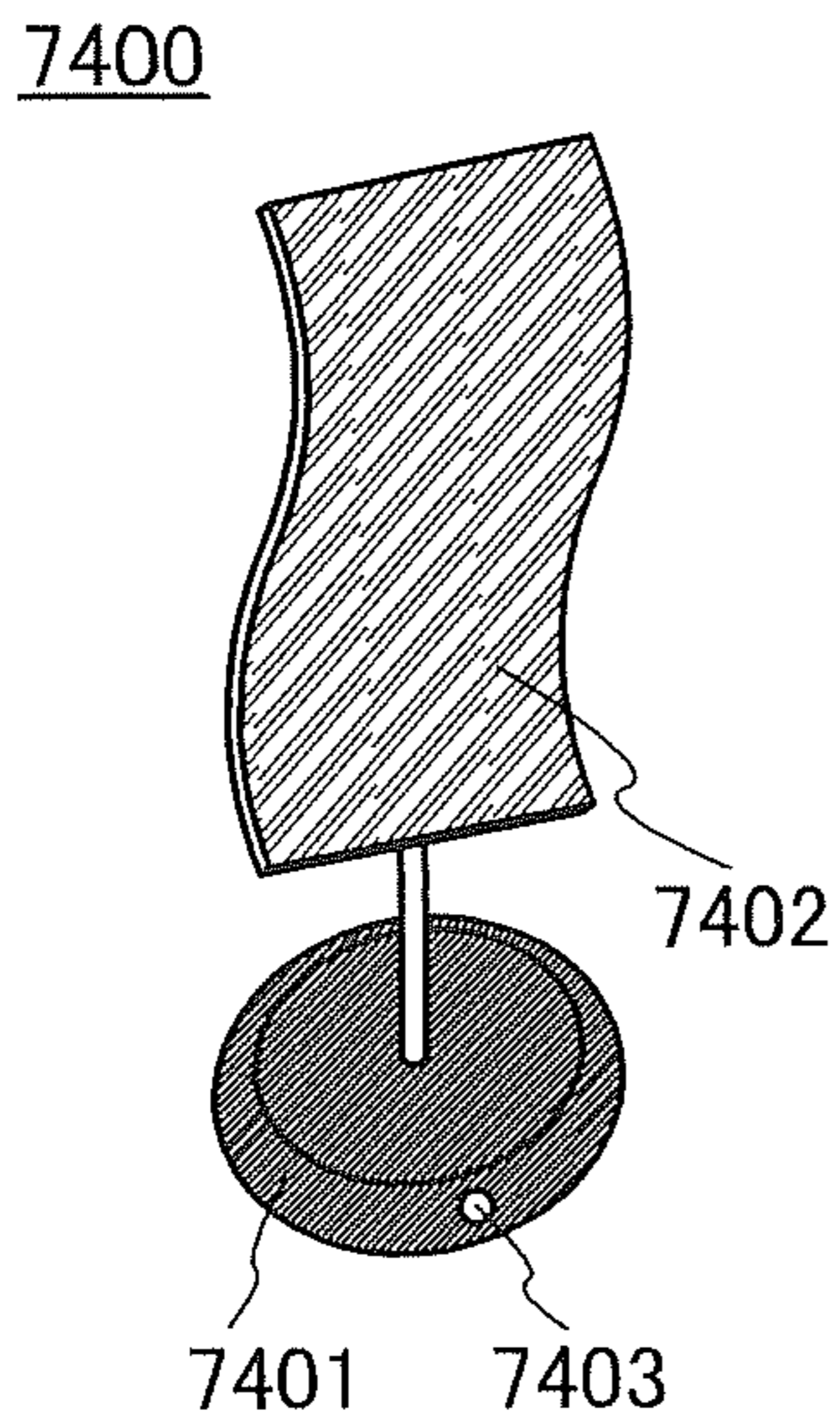


FIG. 38G

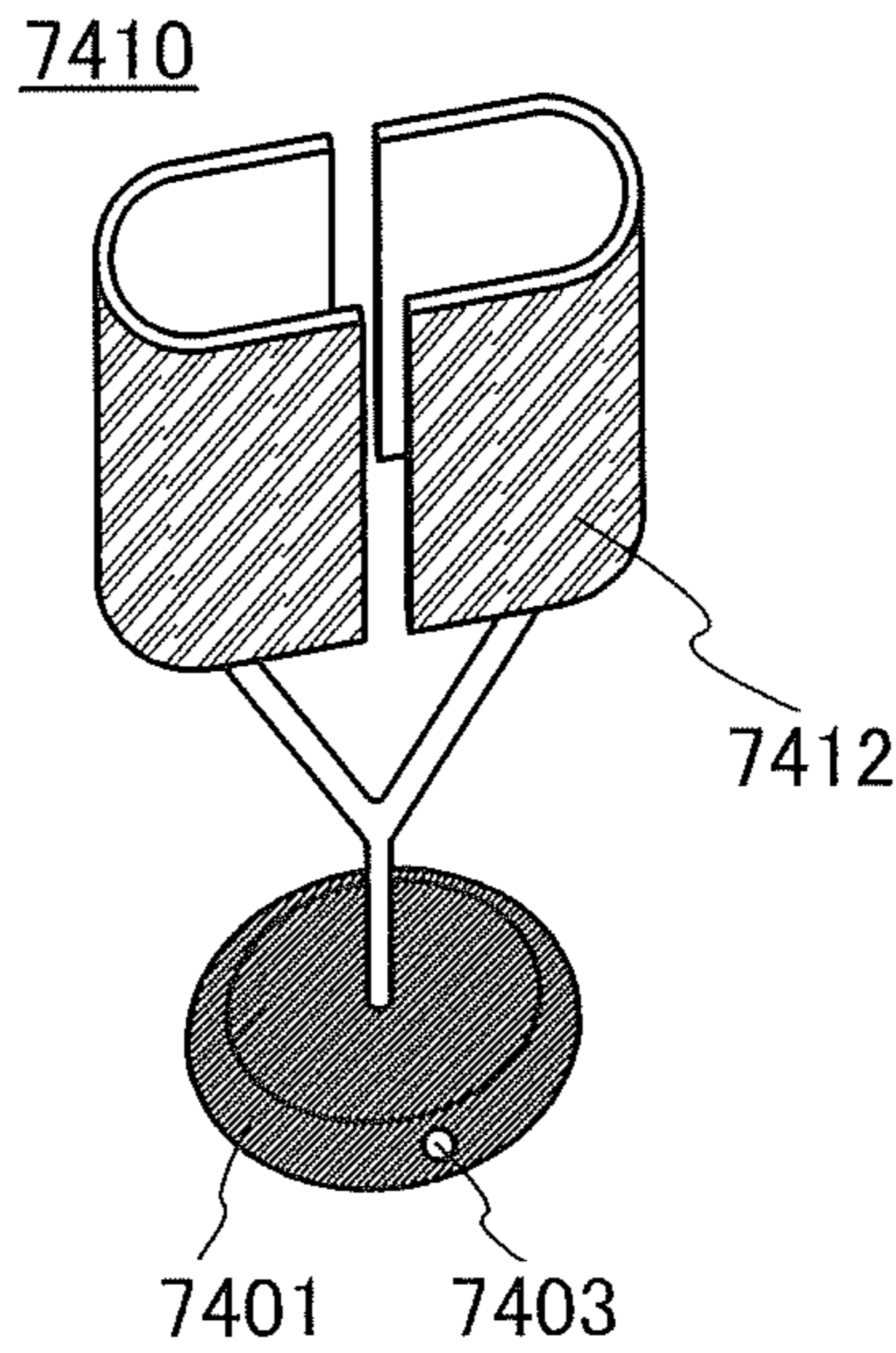


FIG. 38H

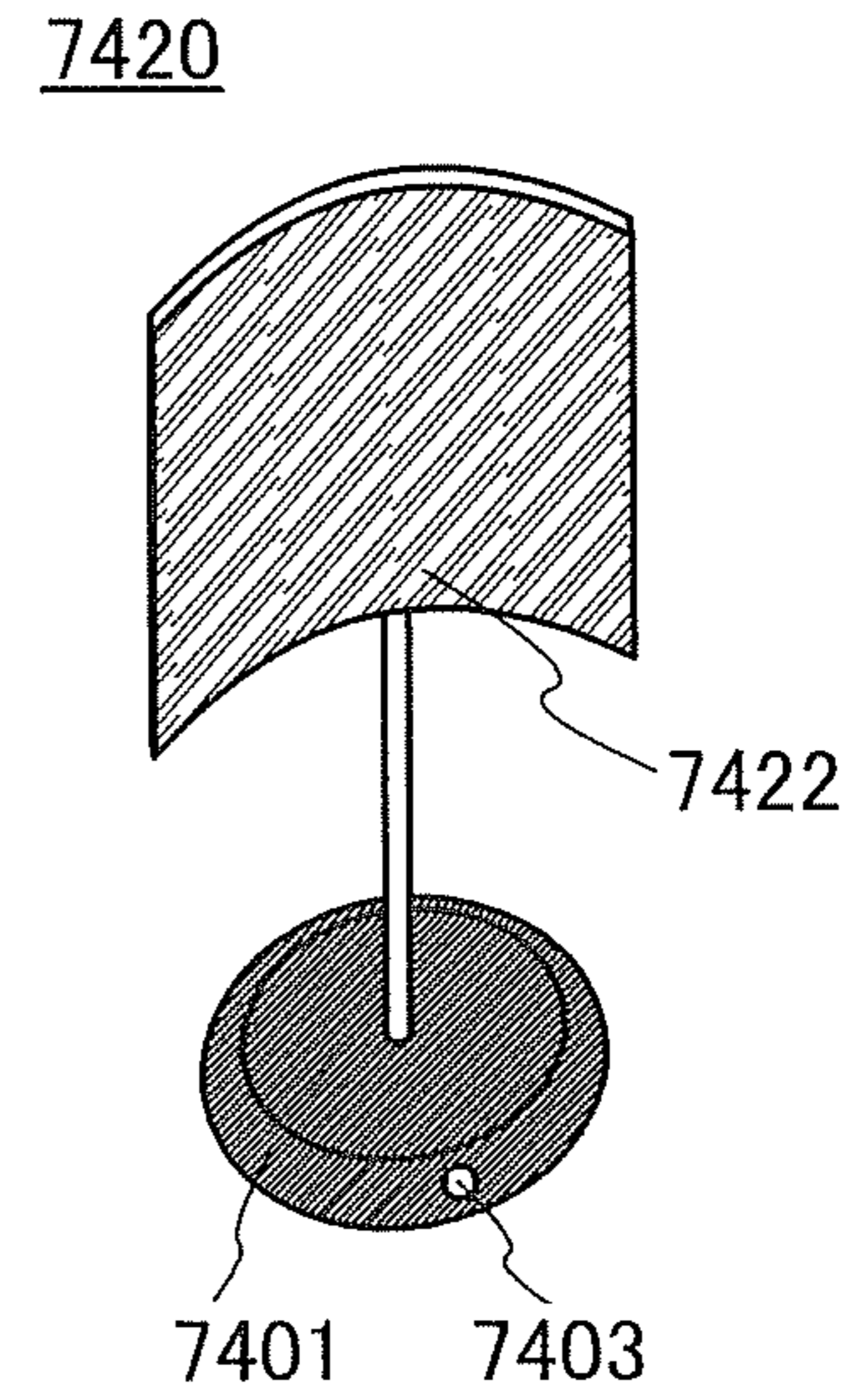


FIG. 39A1

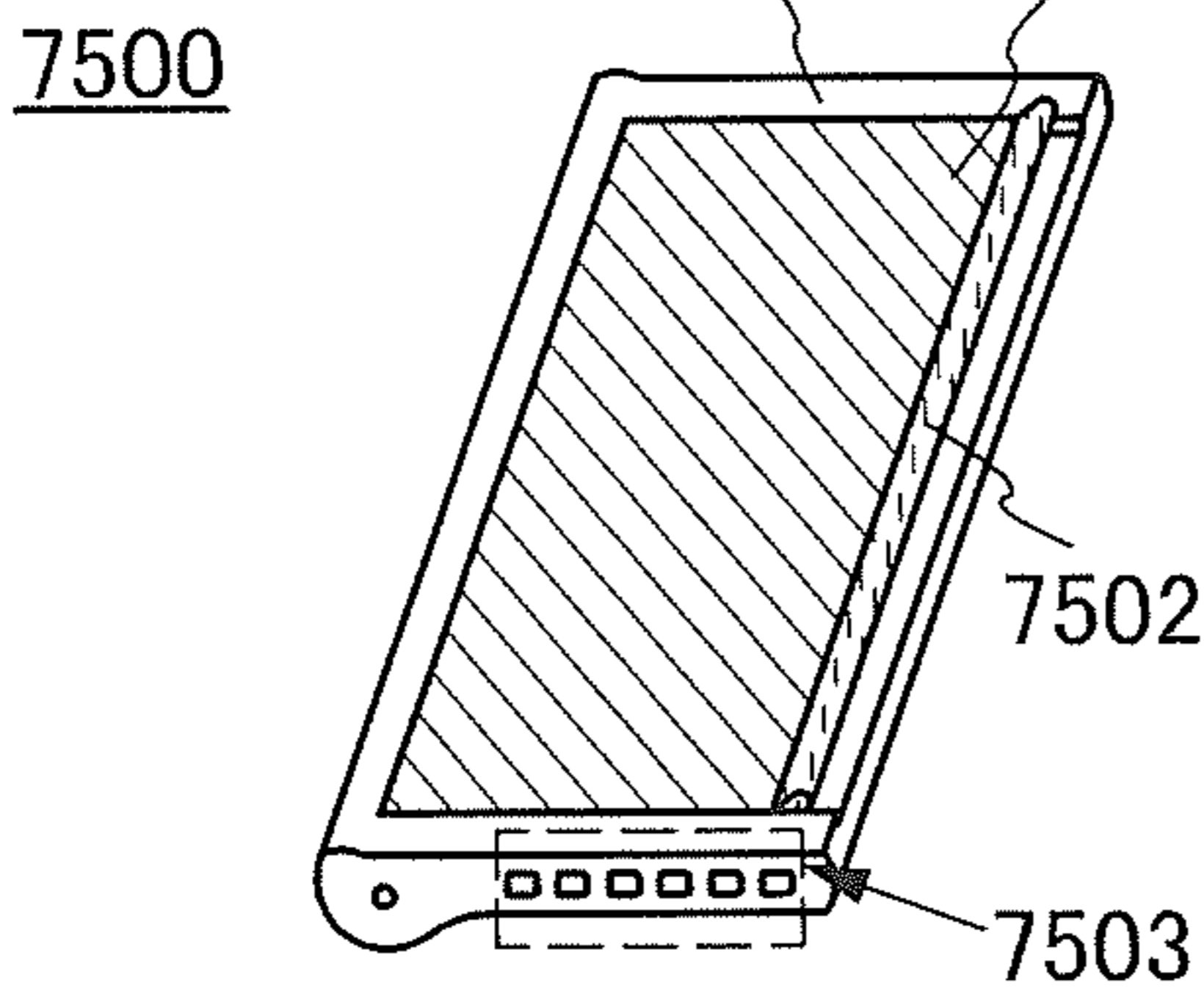


FIG. 39B

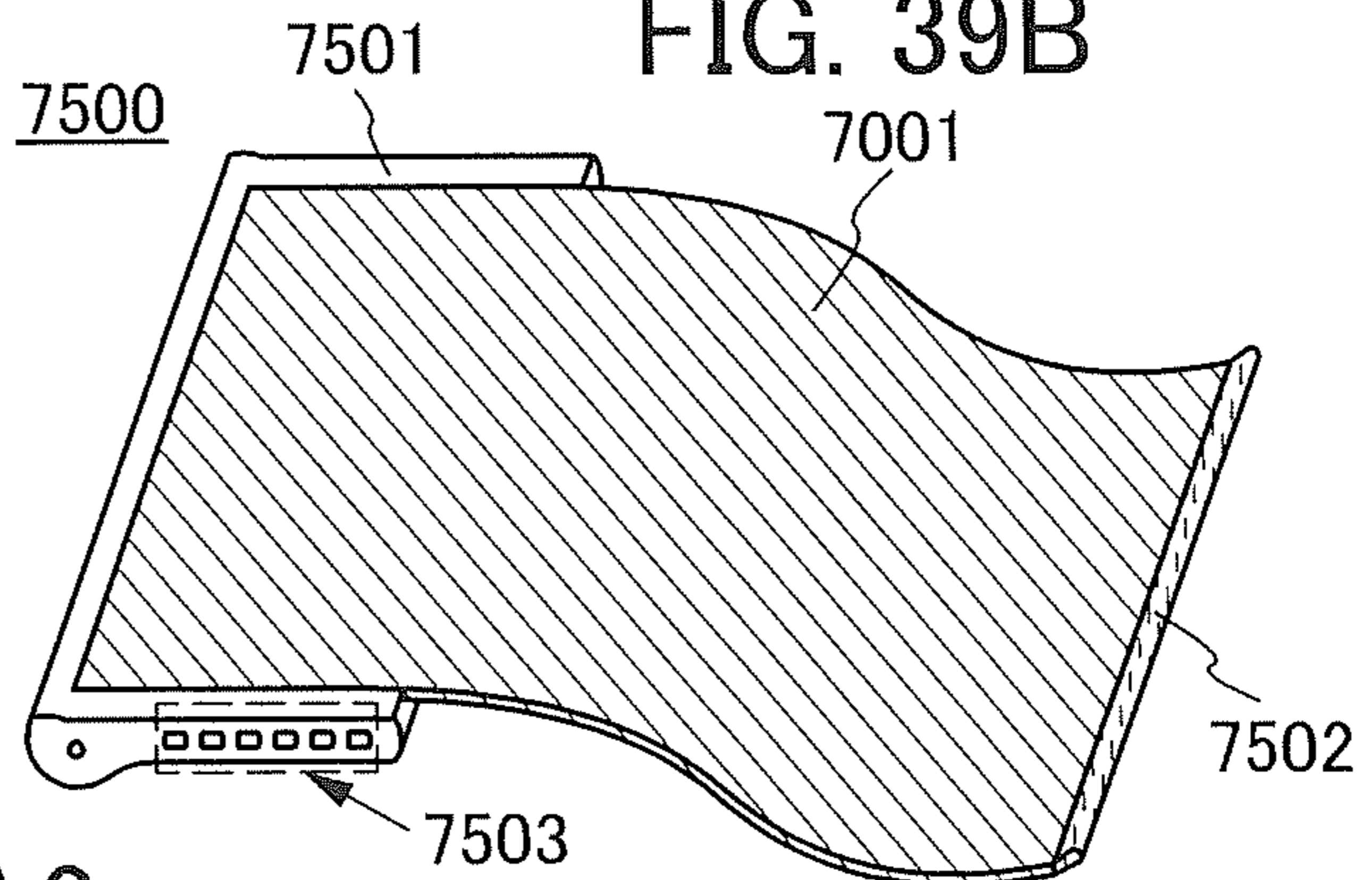


FIG. 39A2



FIG. 39C

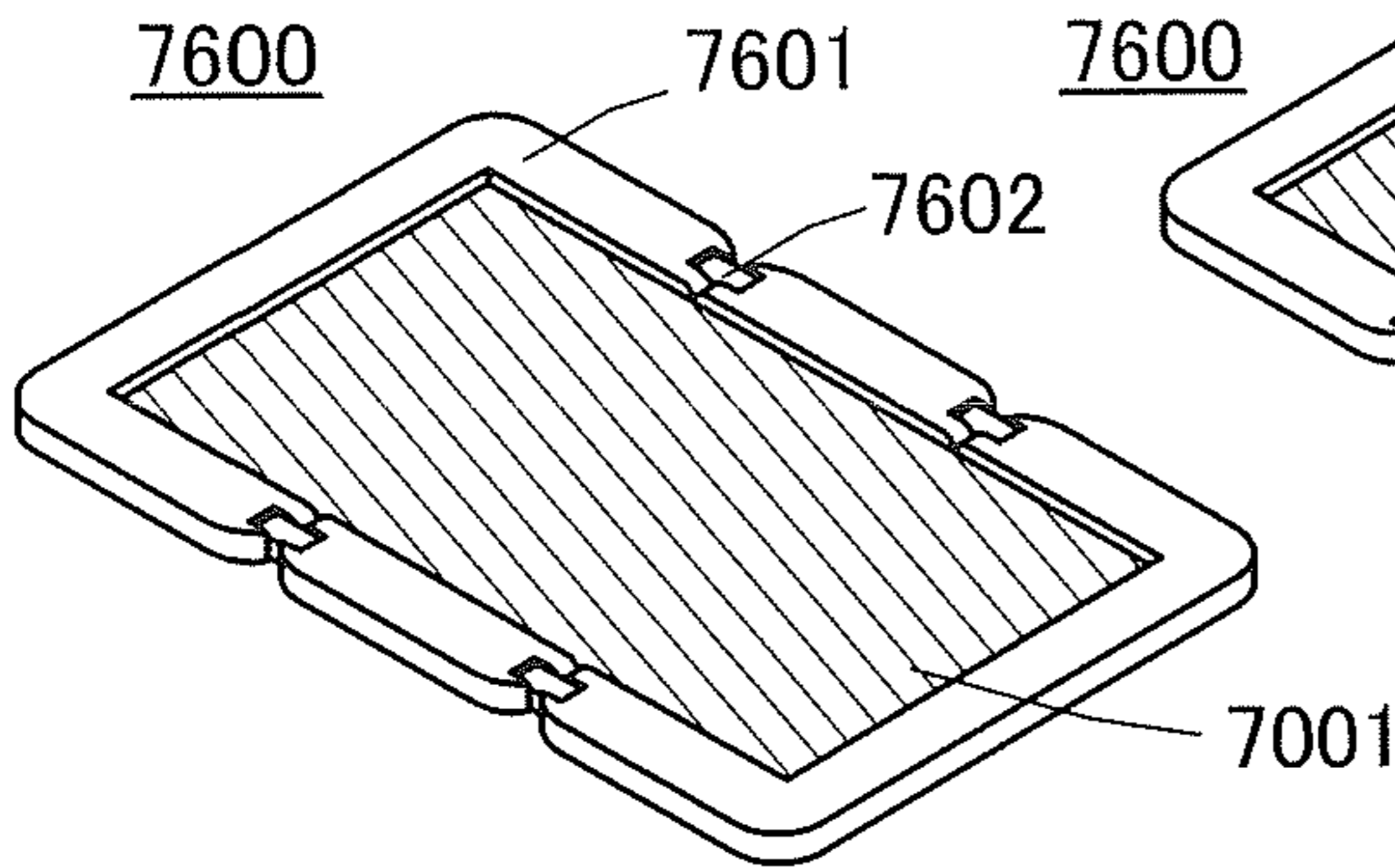


FIG. 39D

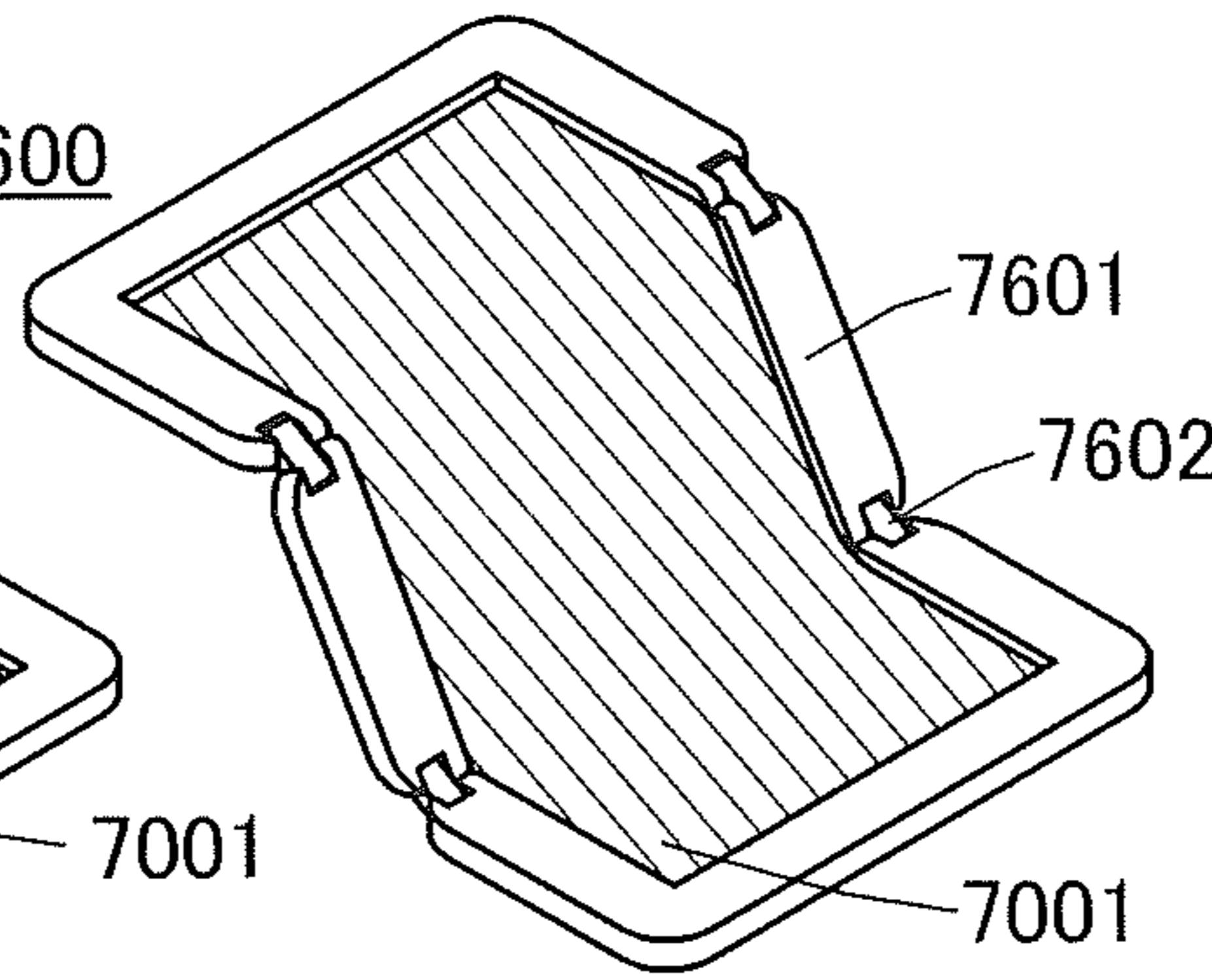


FIG. 39E

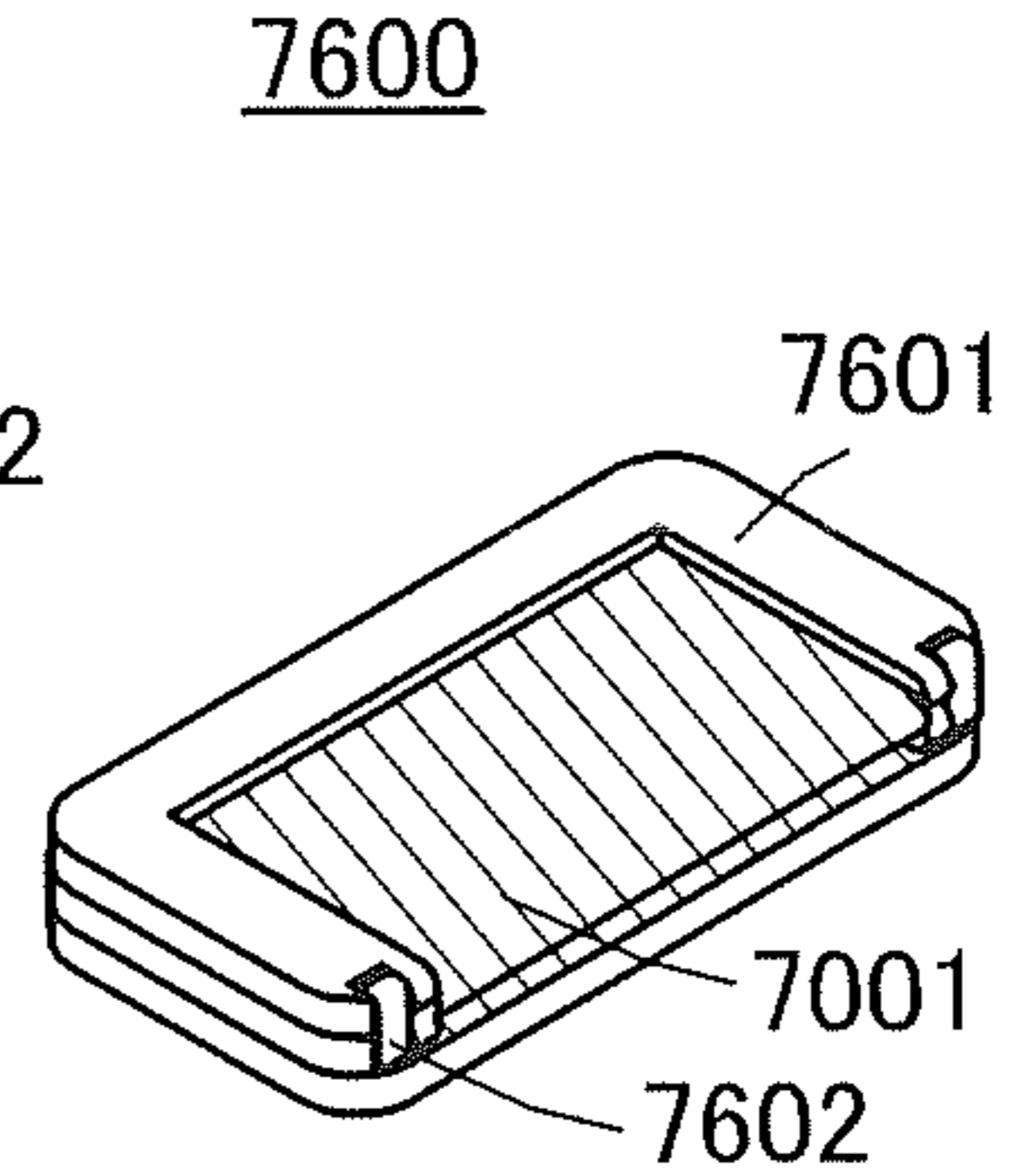


FIG. 39F

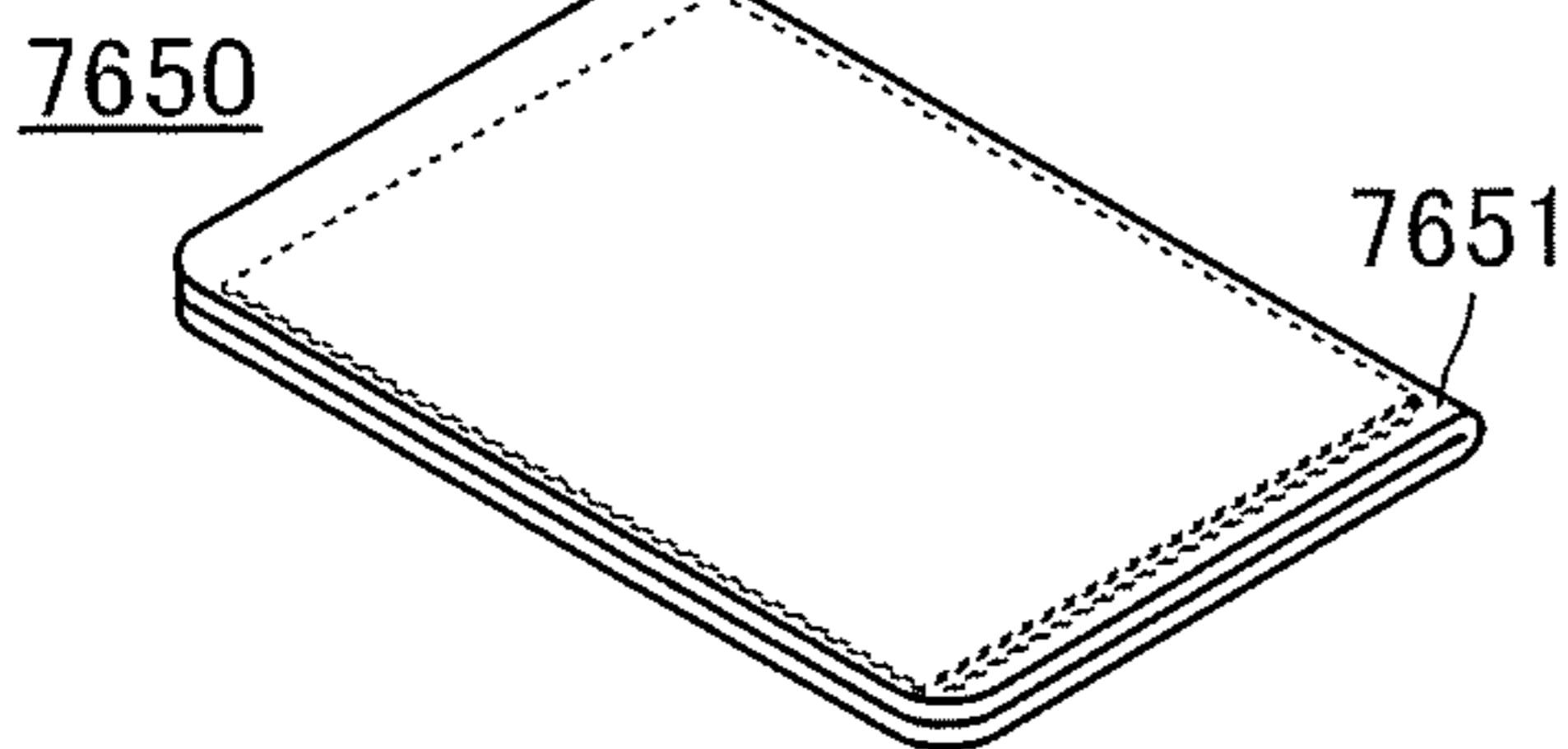


FIG. 39G

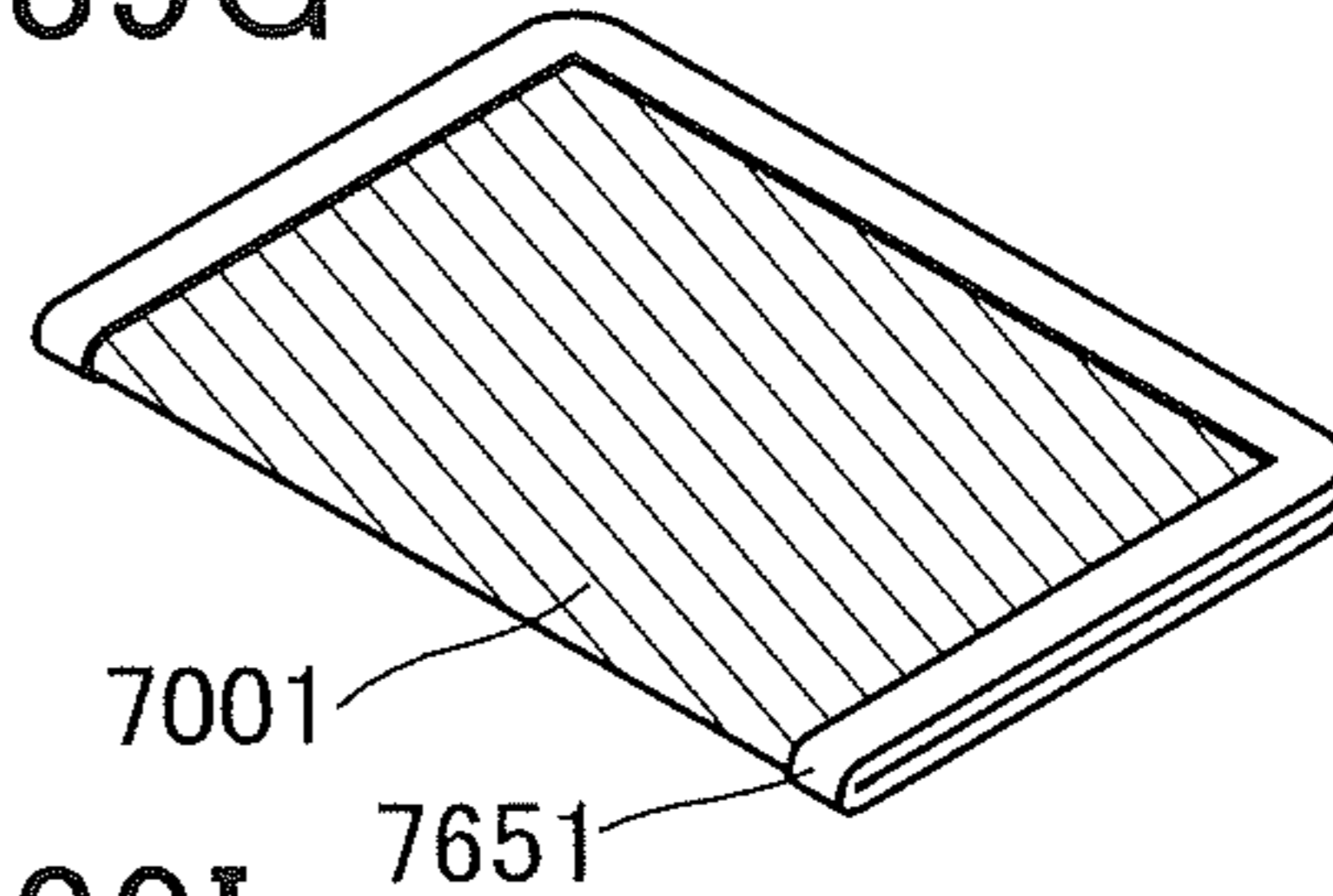


FIG. 39H

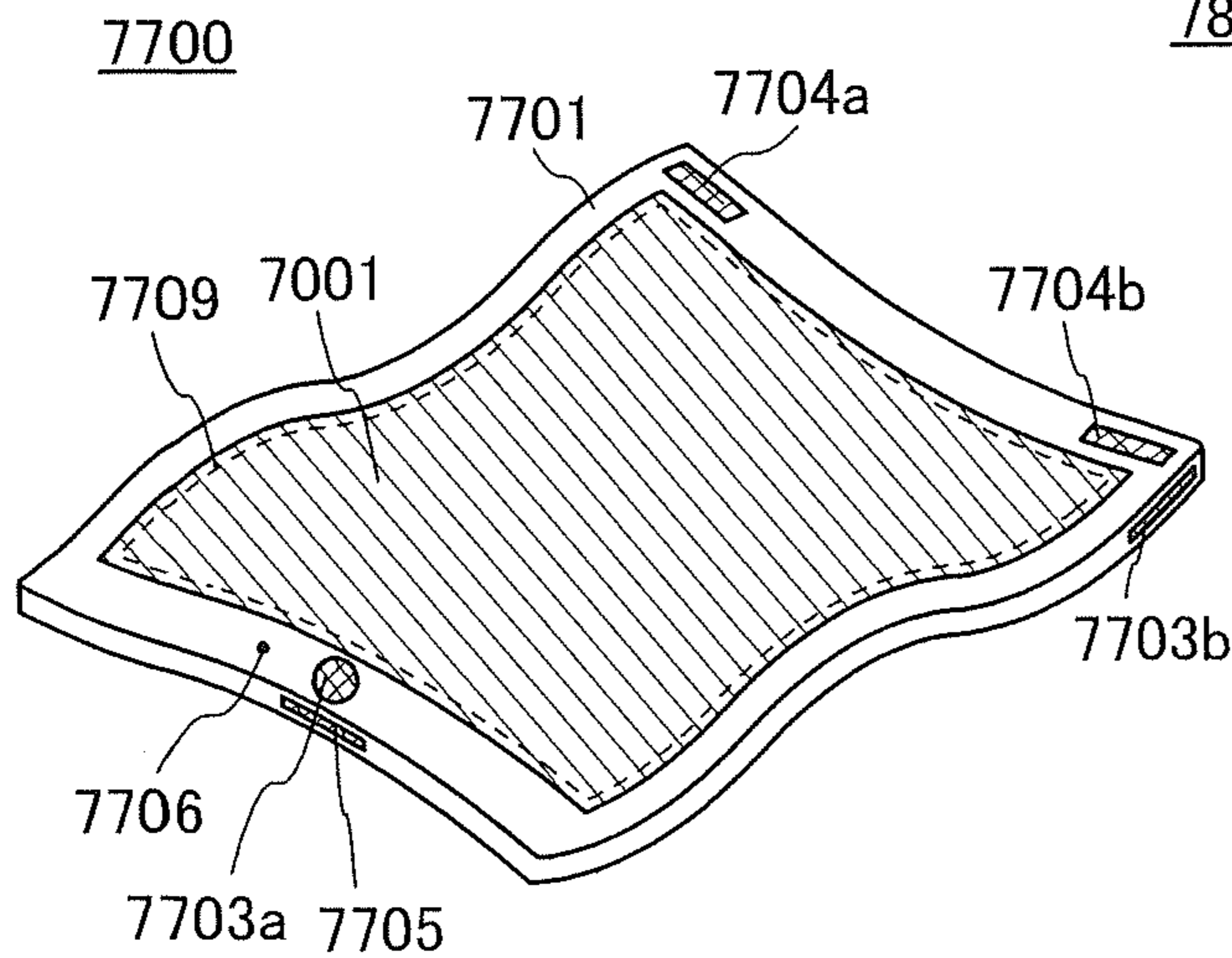


FIG. 39I

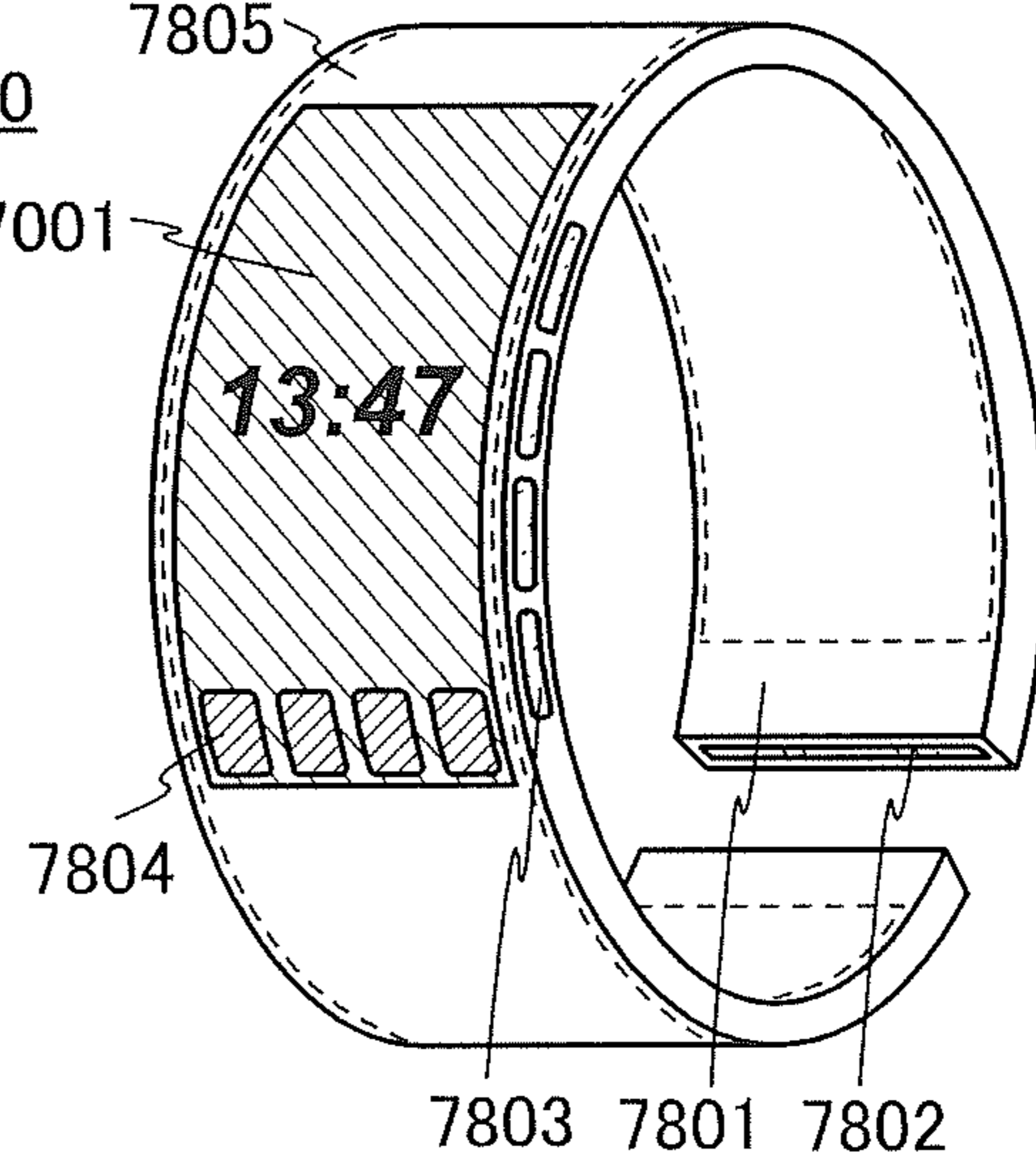


FIG. 40A

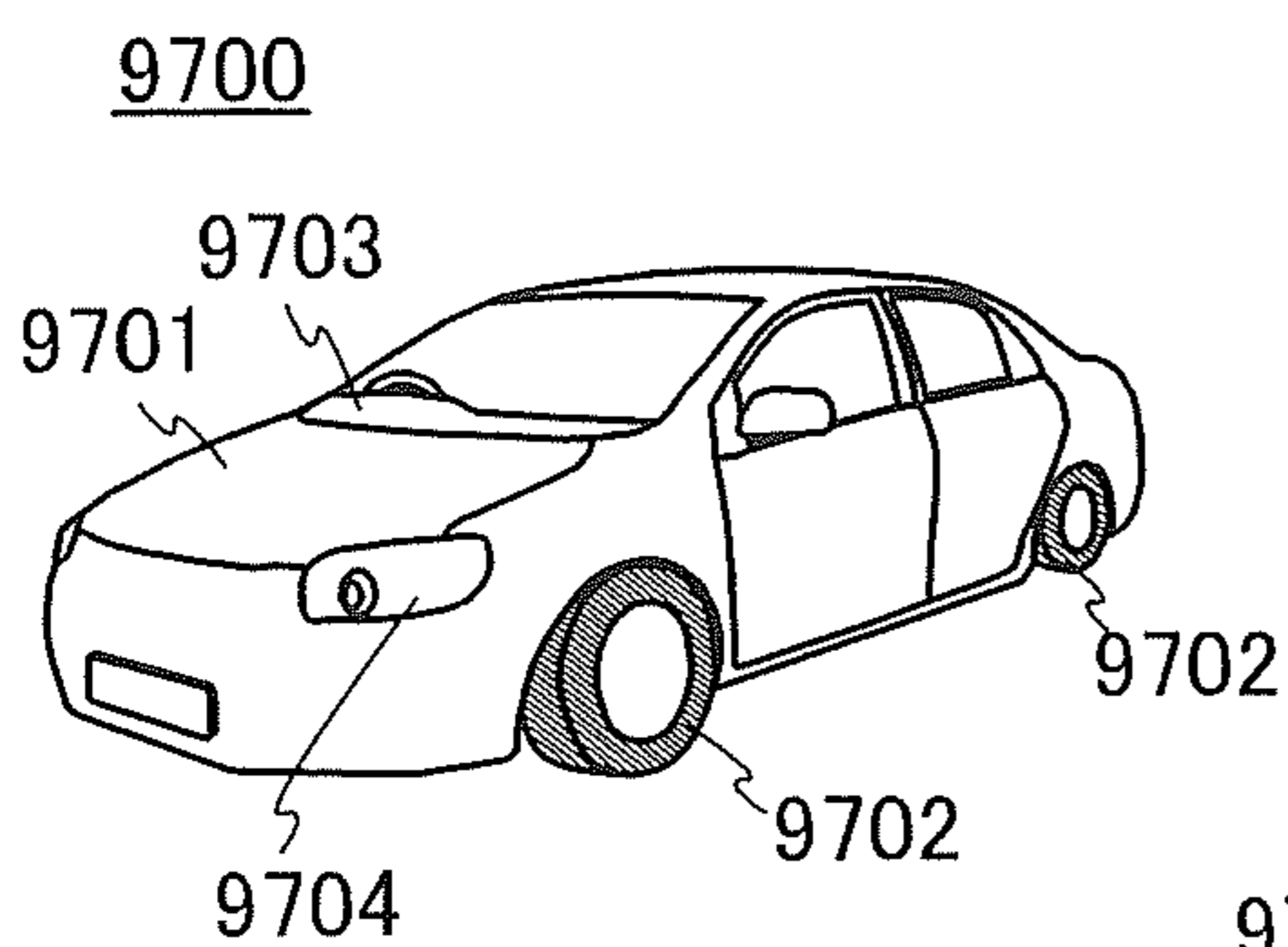


FIG. 40B

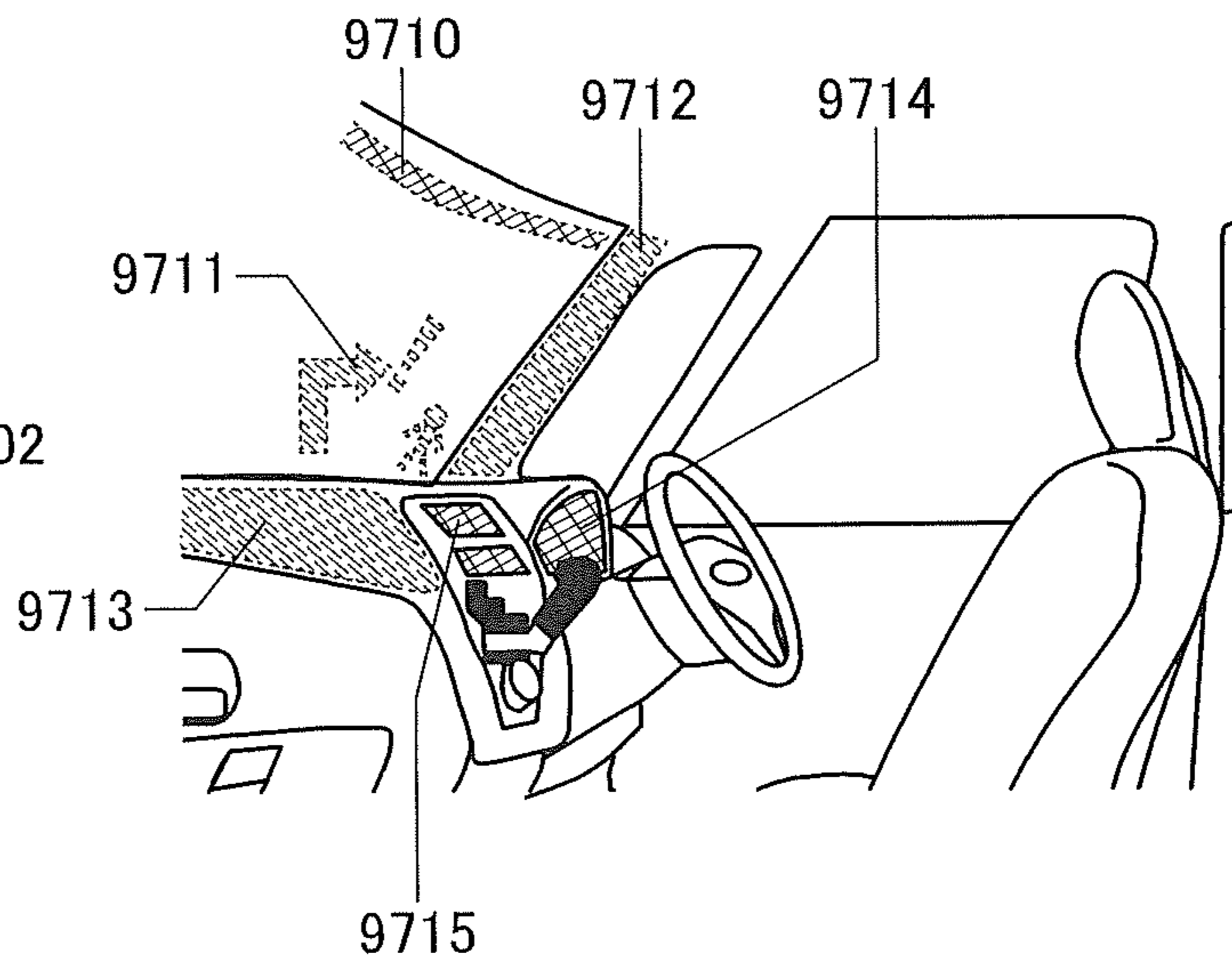


FIG. 40C

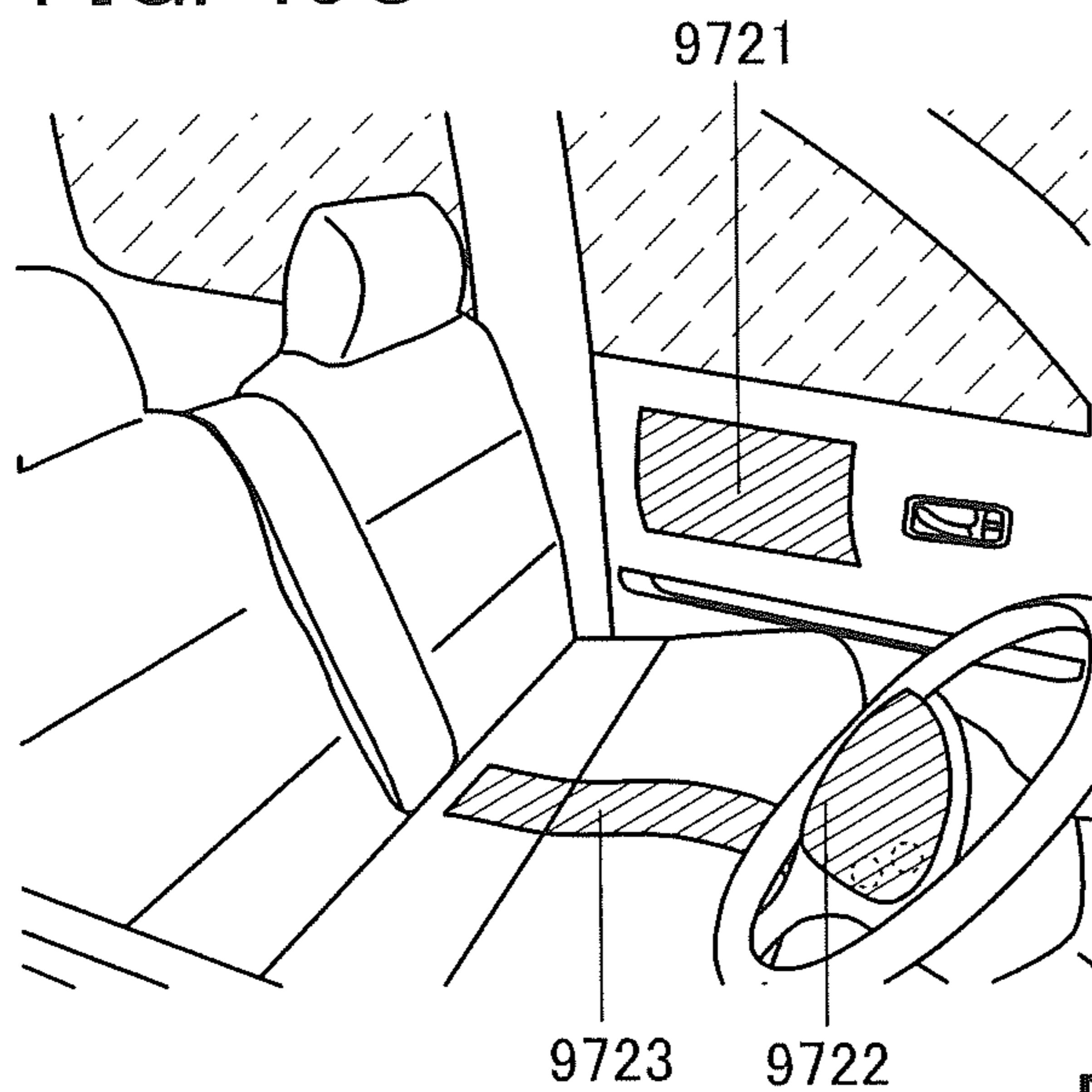


FIG. 40D

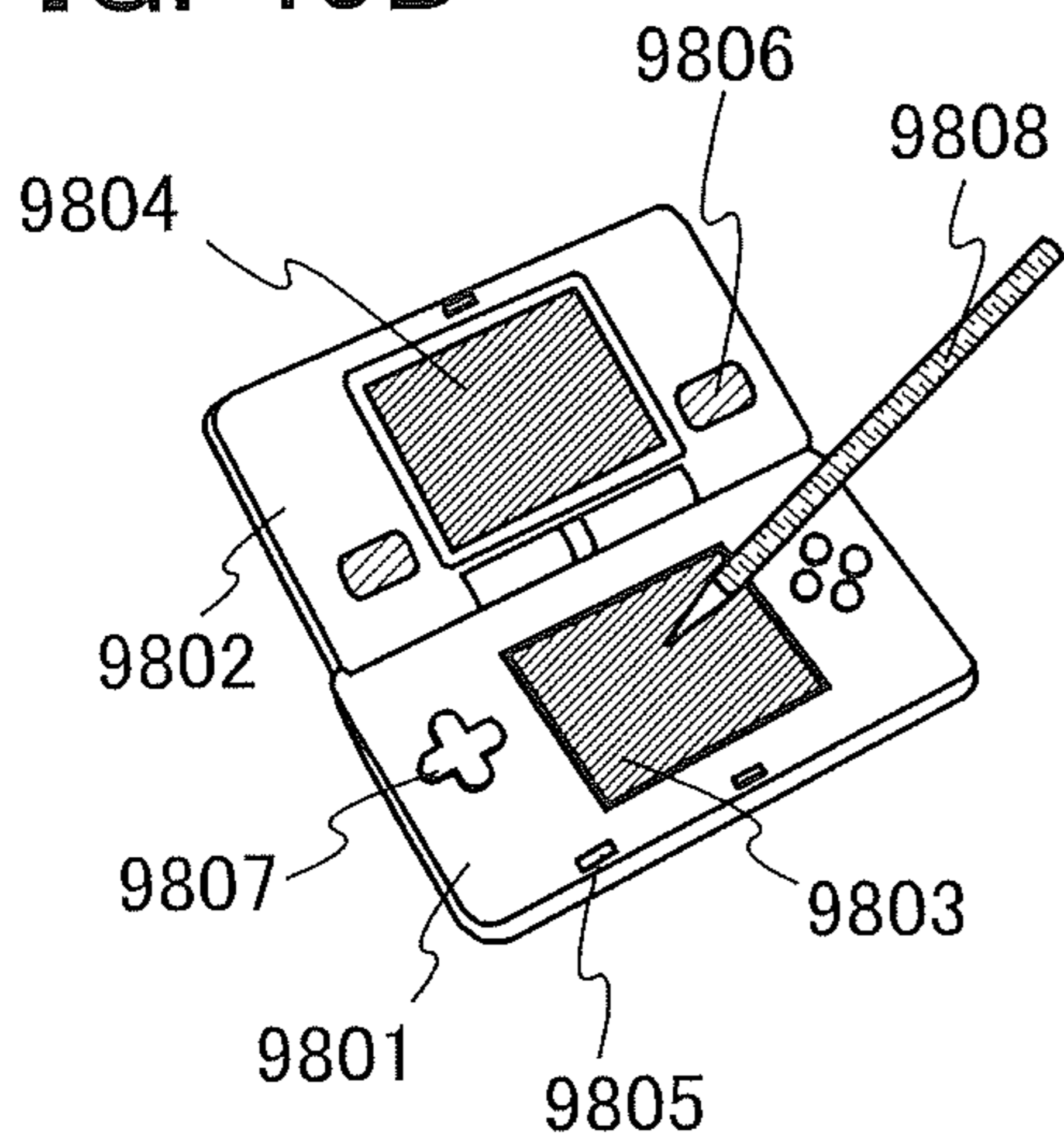


FIG. 40E

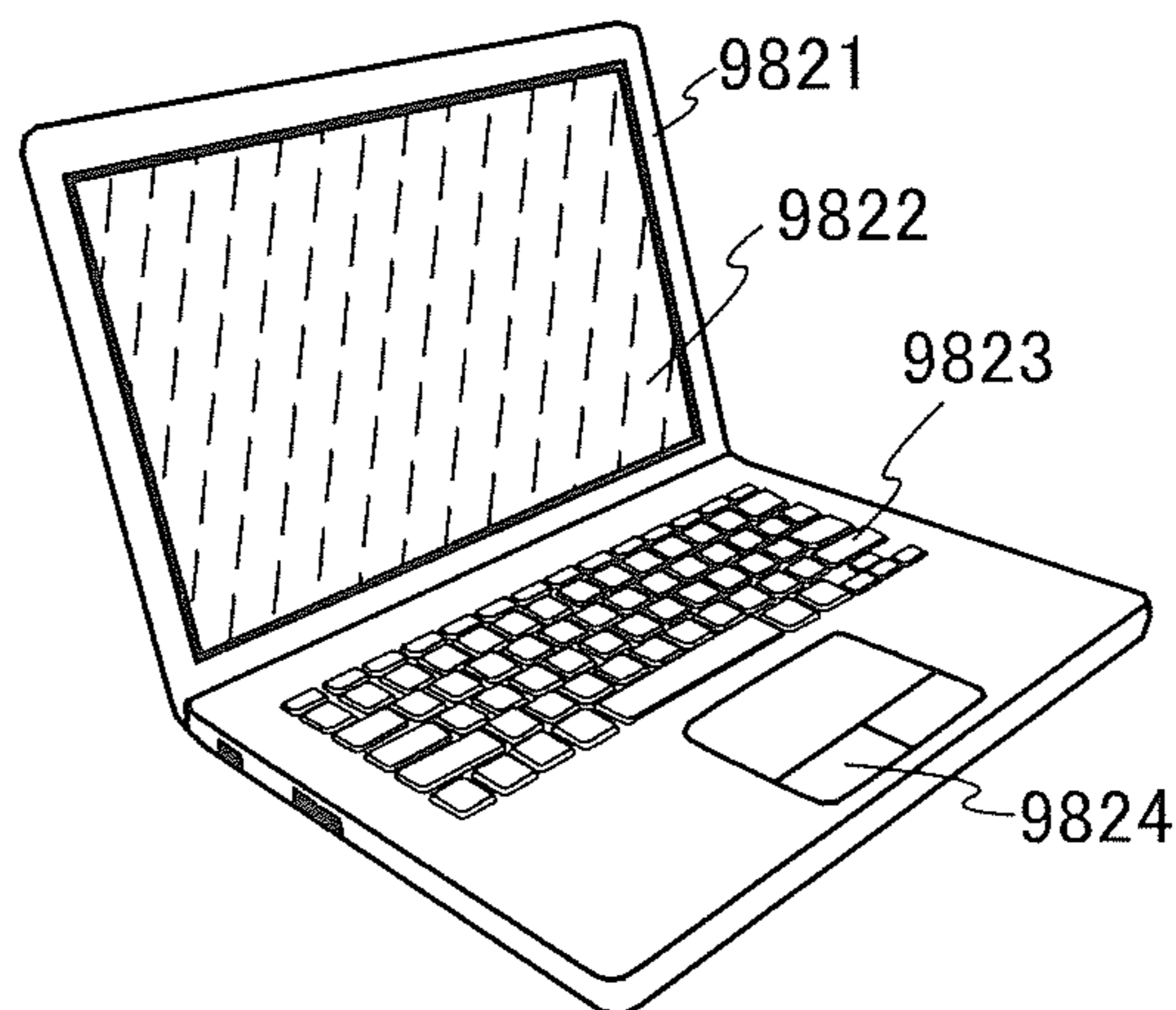


FIG. 41A

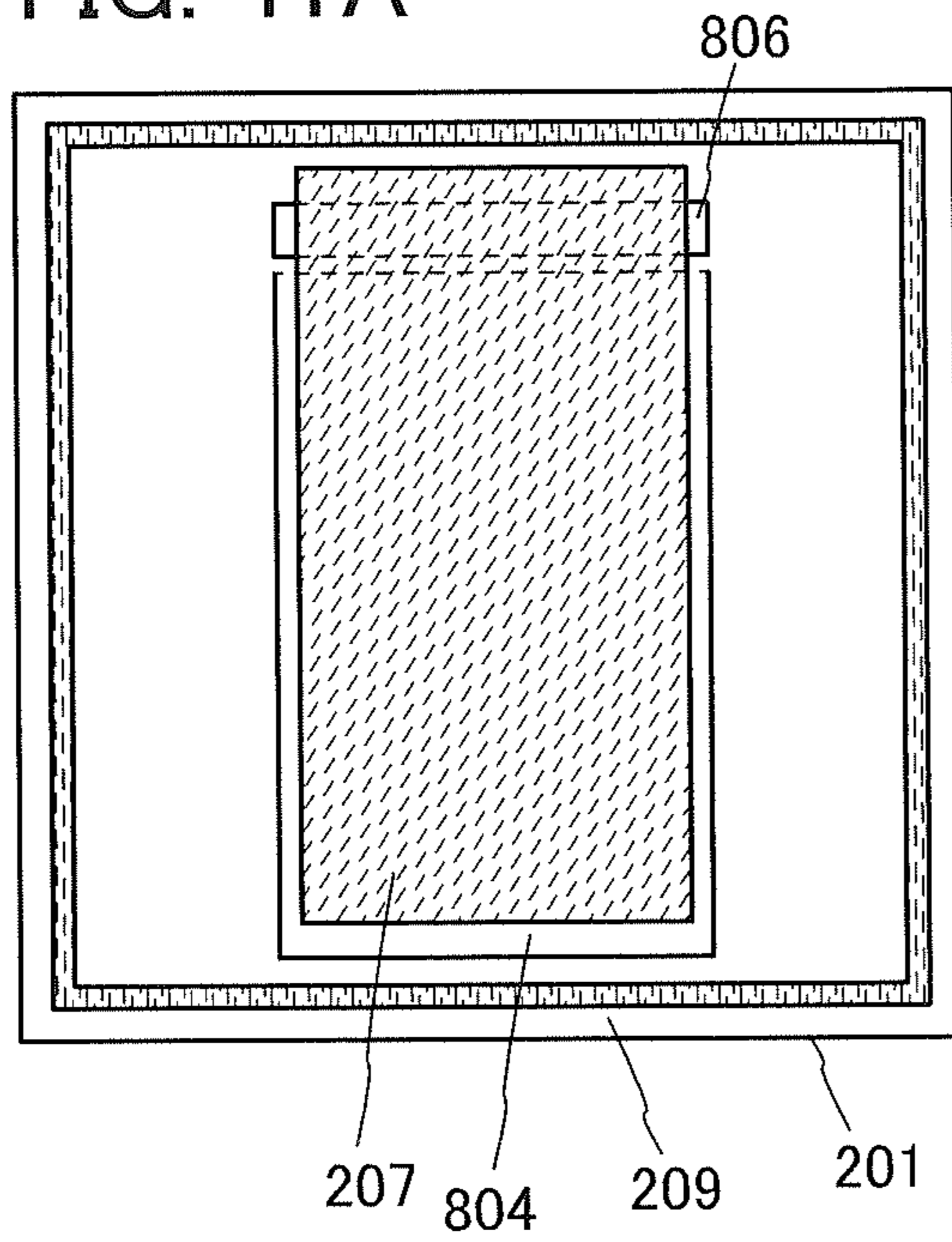


FIG. 41B

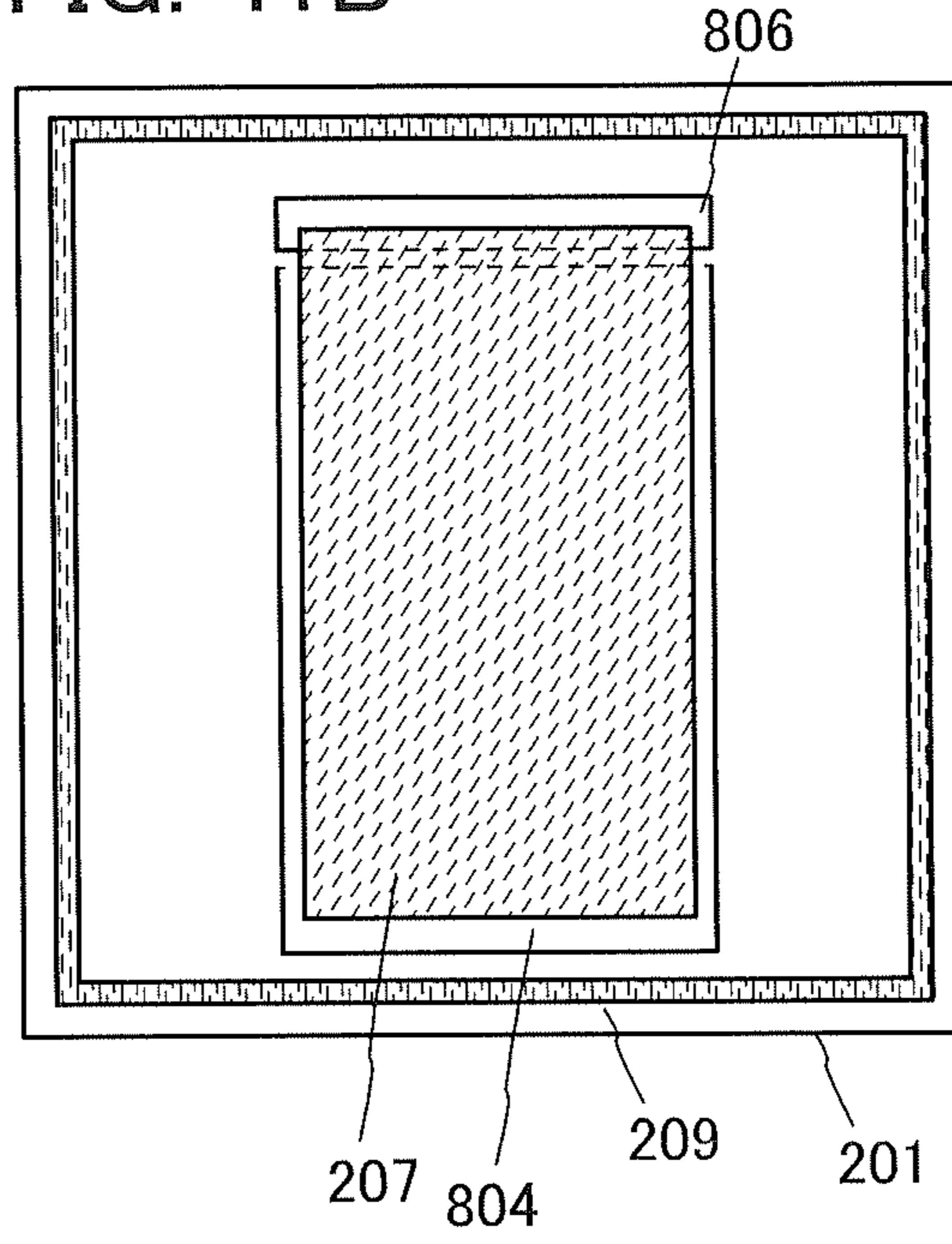


FIG. 41C

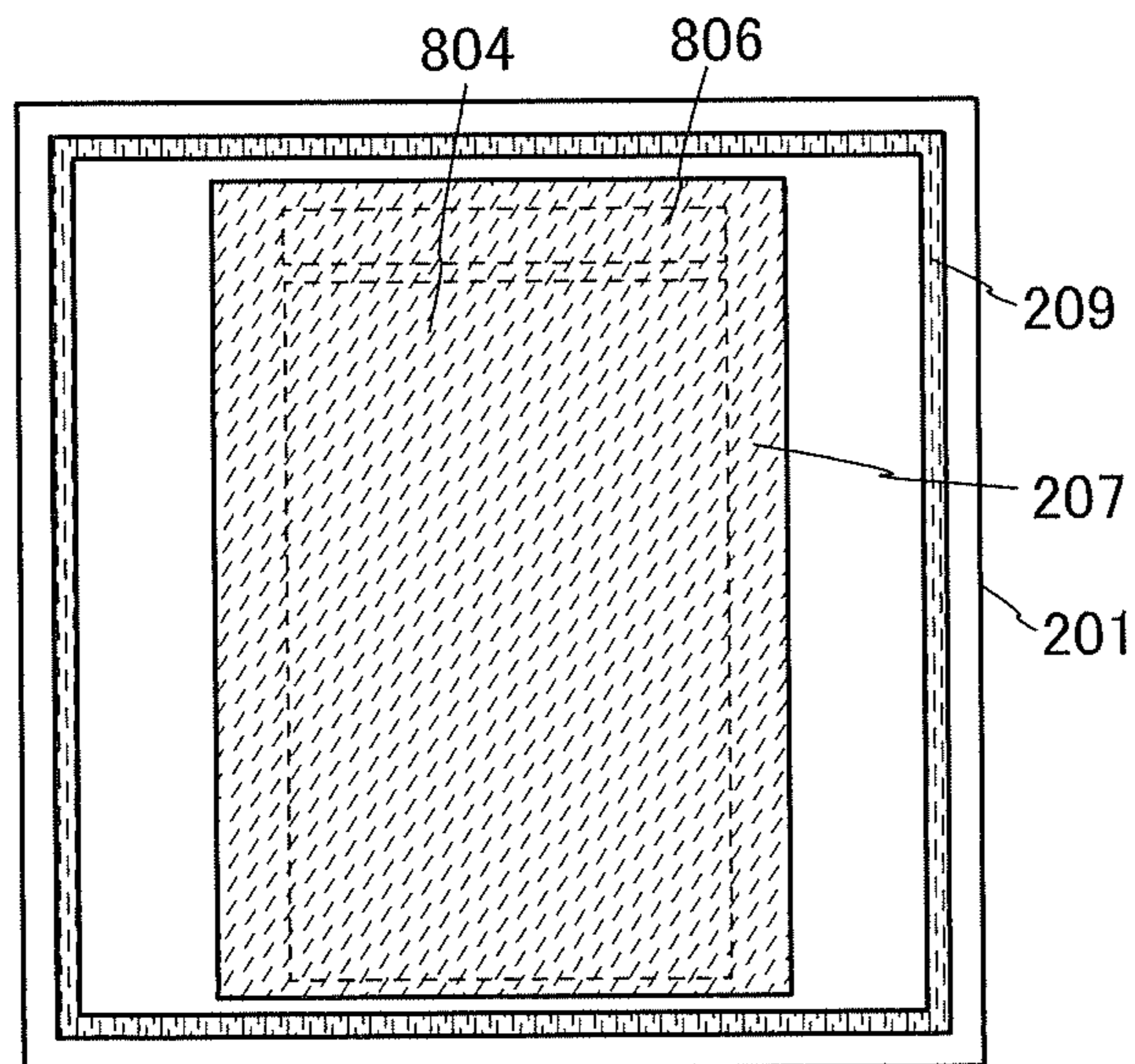


FIG. 42A

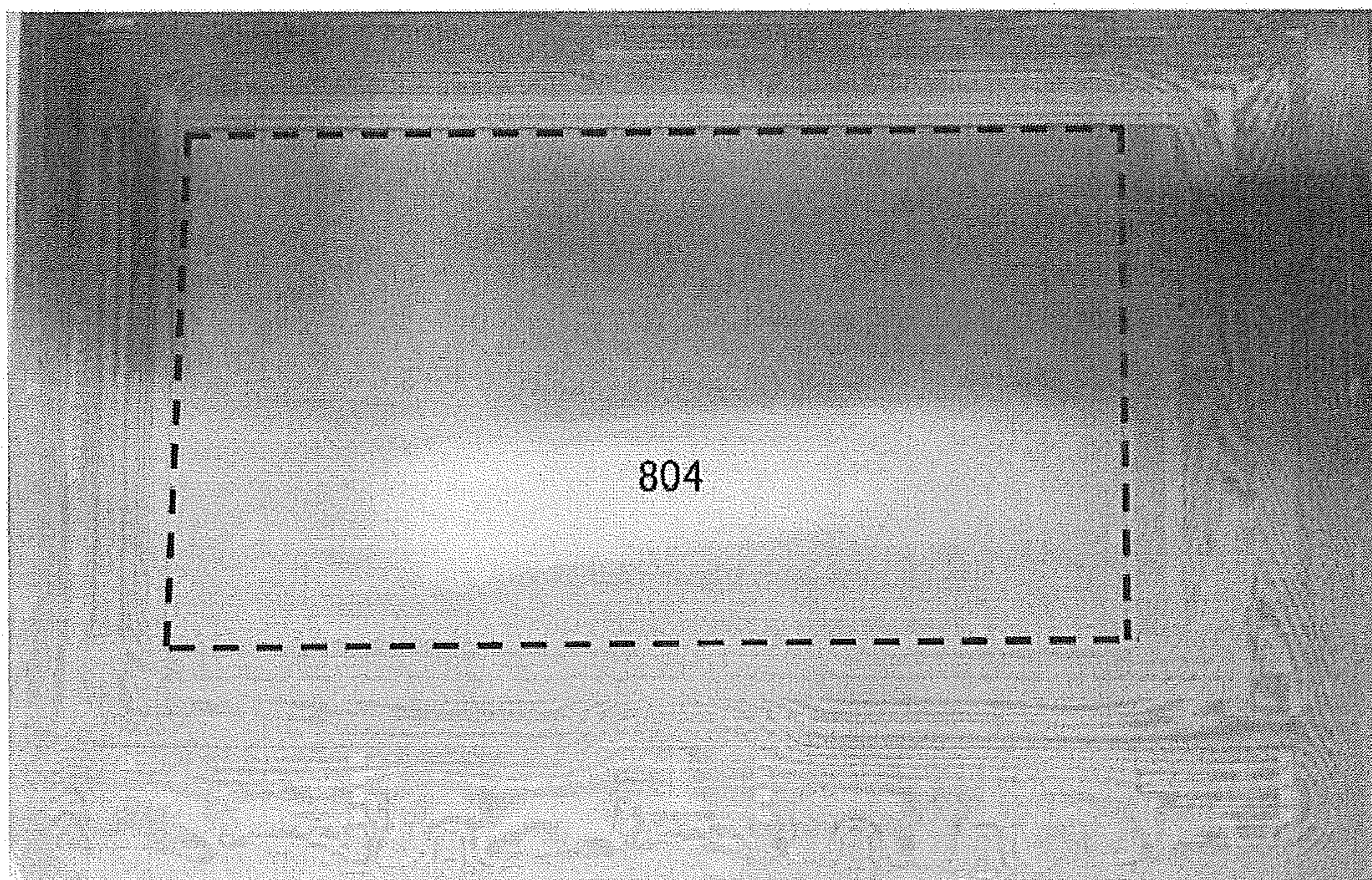


FIG. 42B

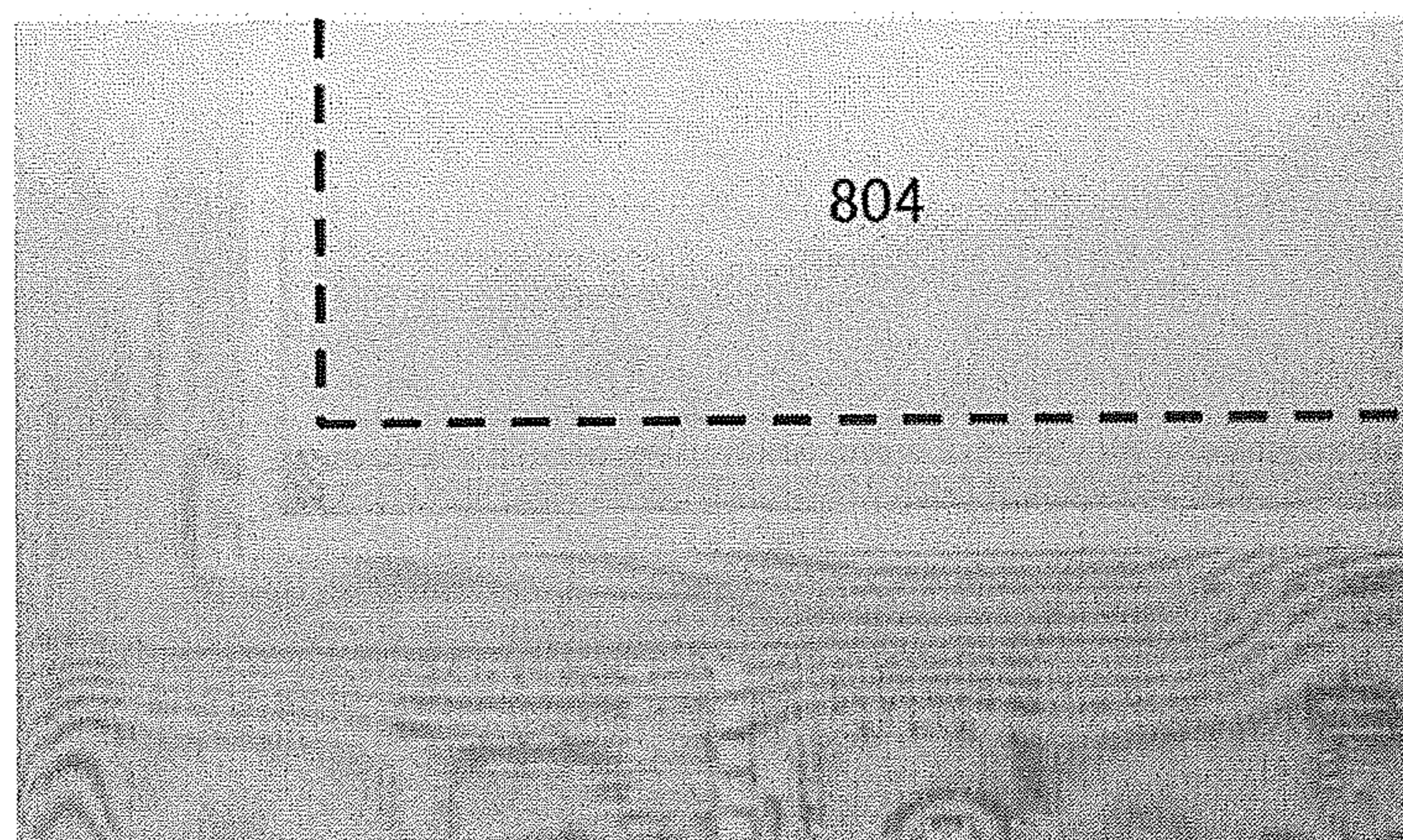


FIG. 43A

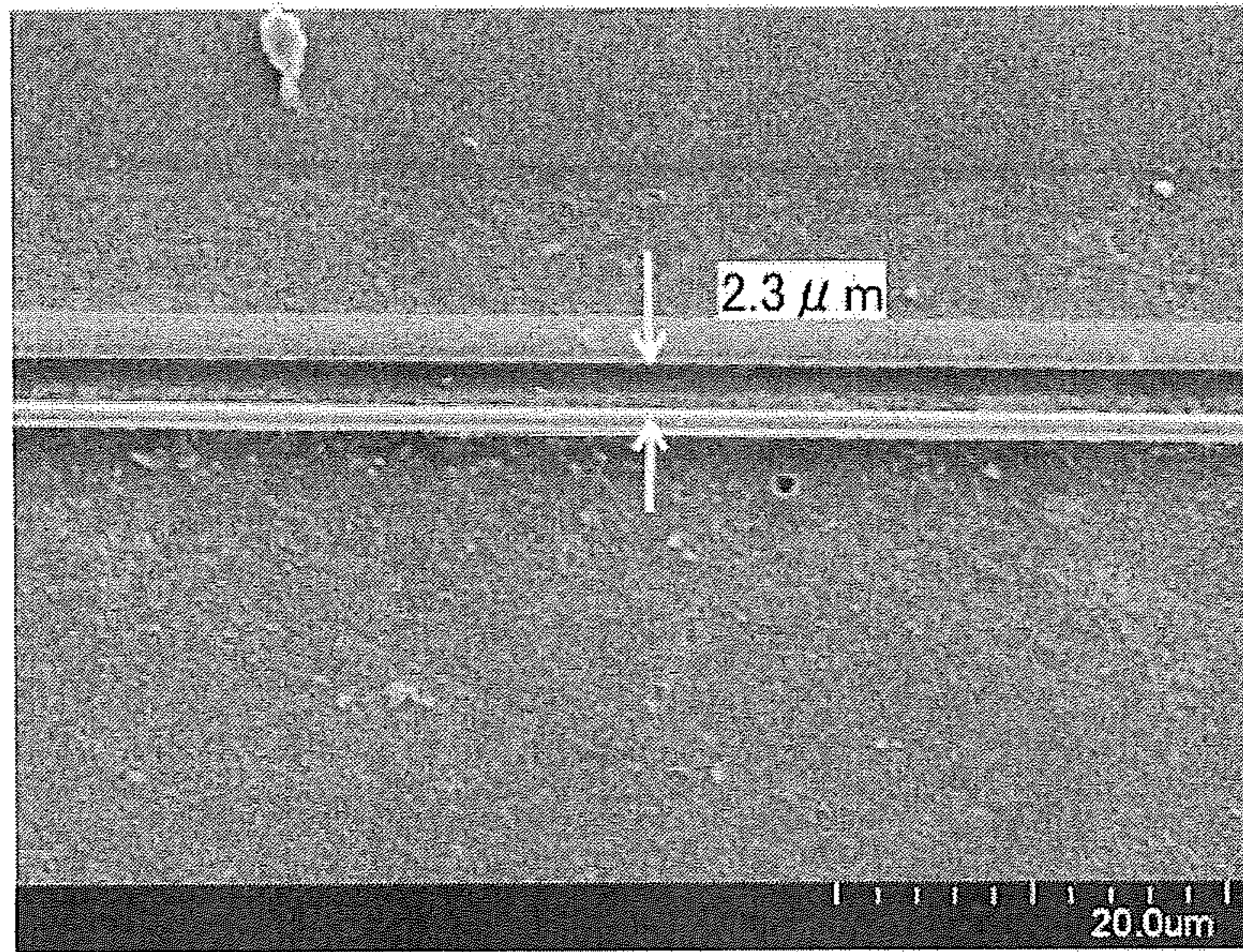


FIG. 43B

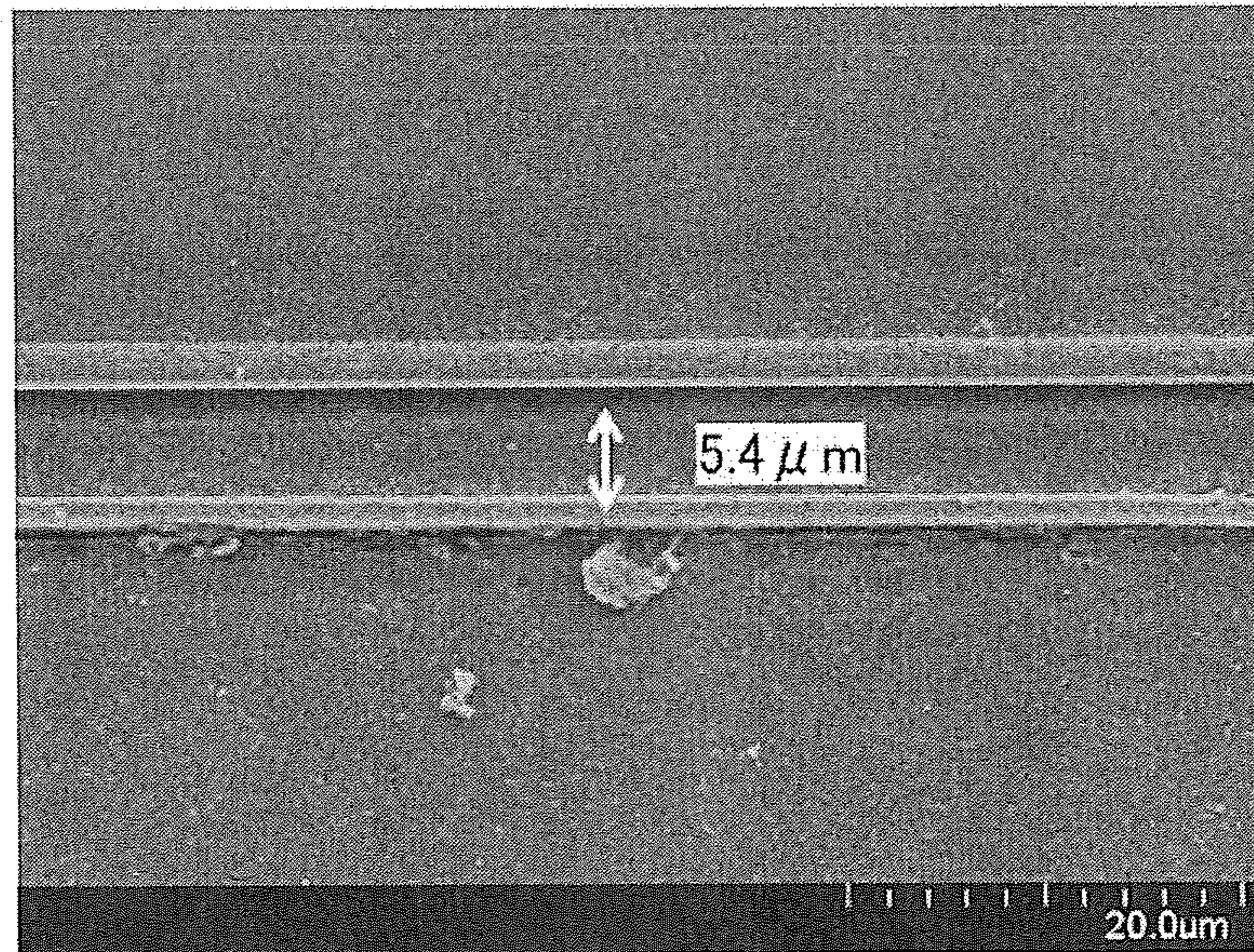


FIG. 43C

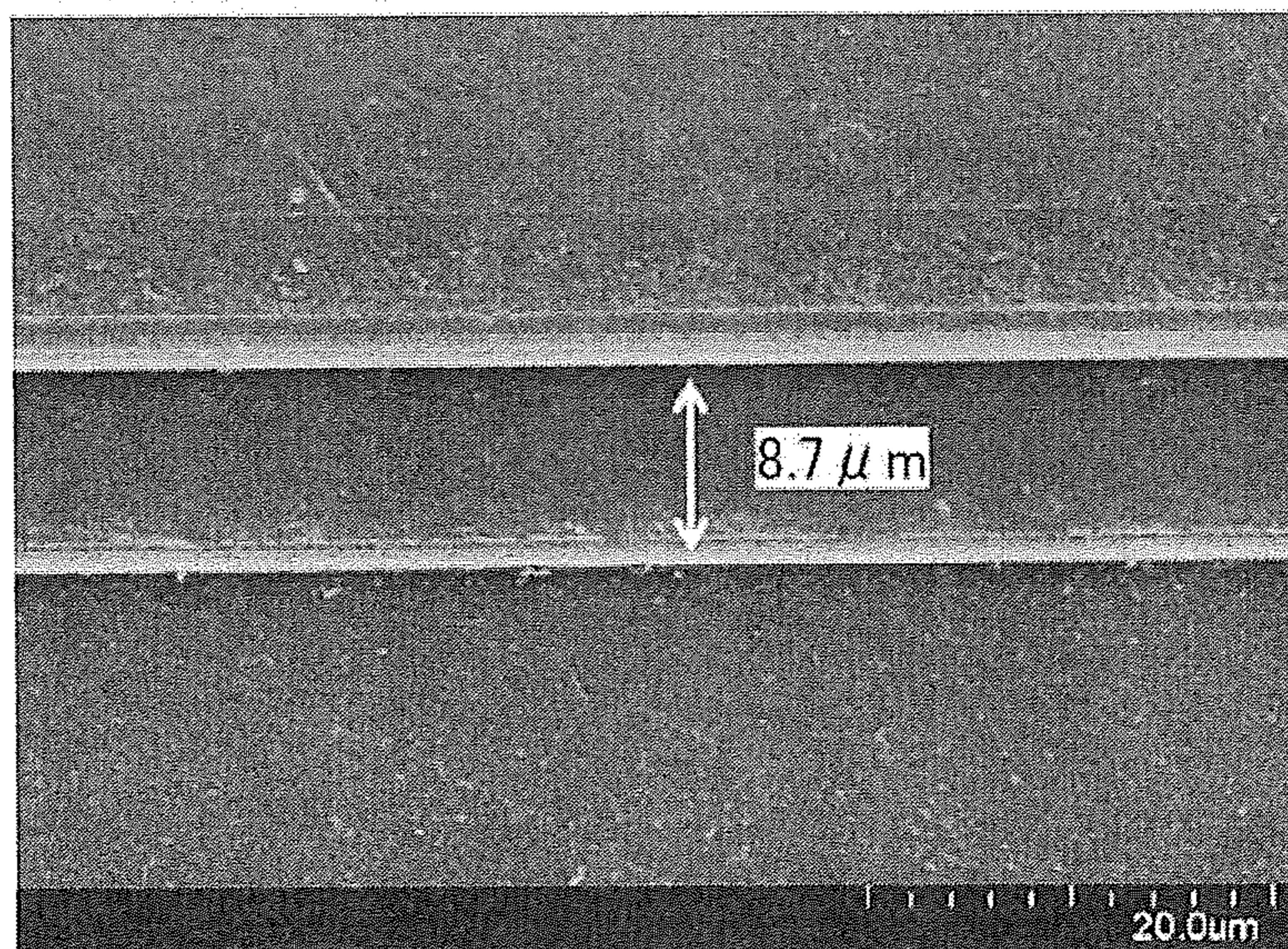


FIG. 44A

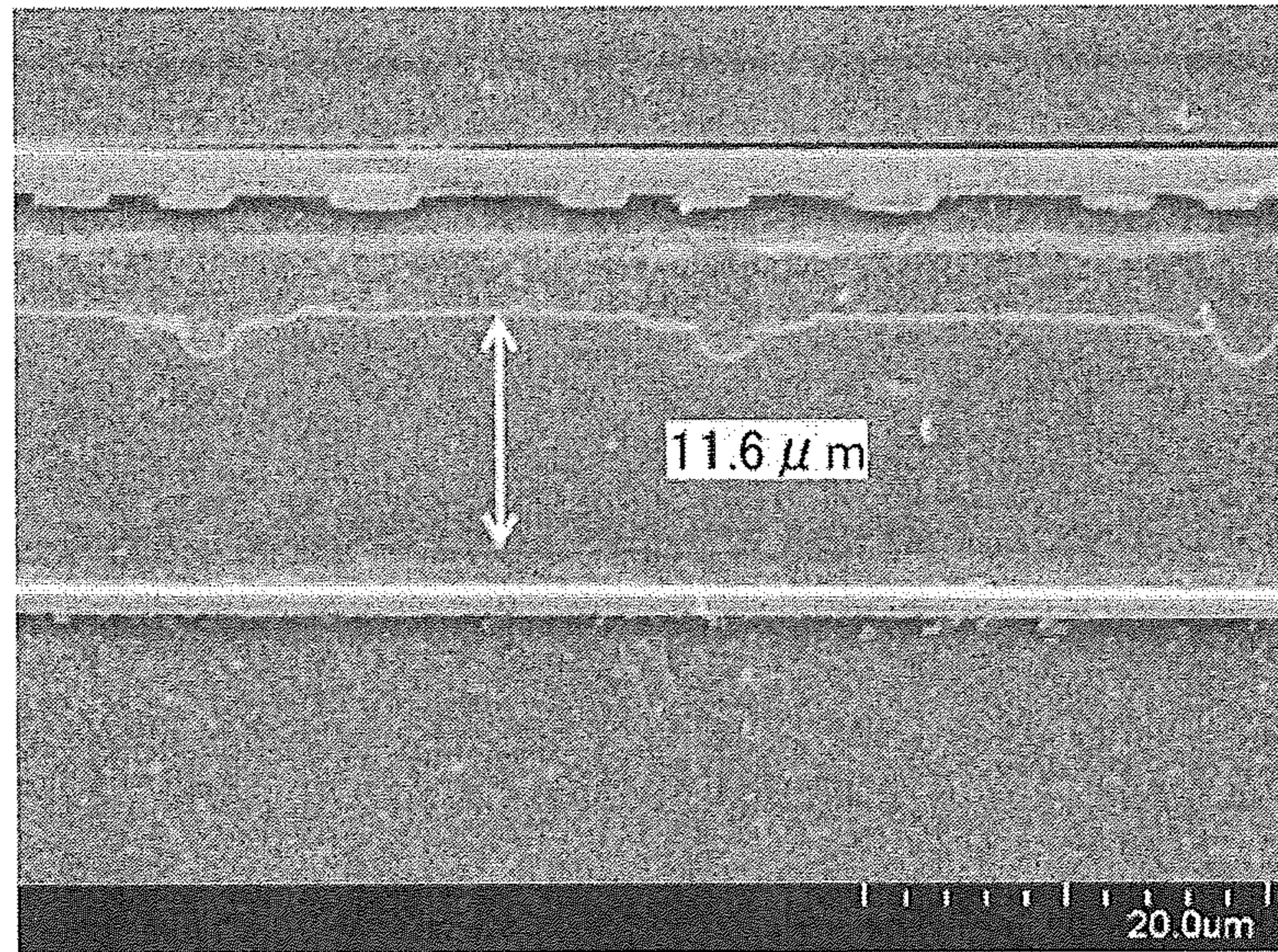
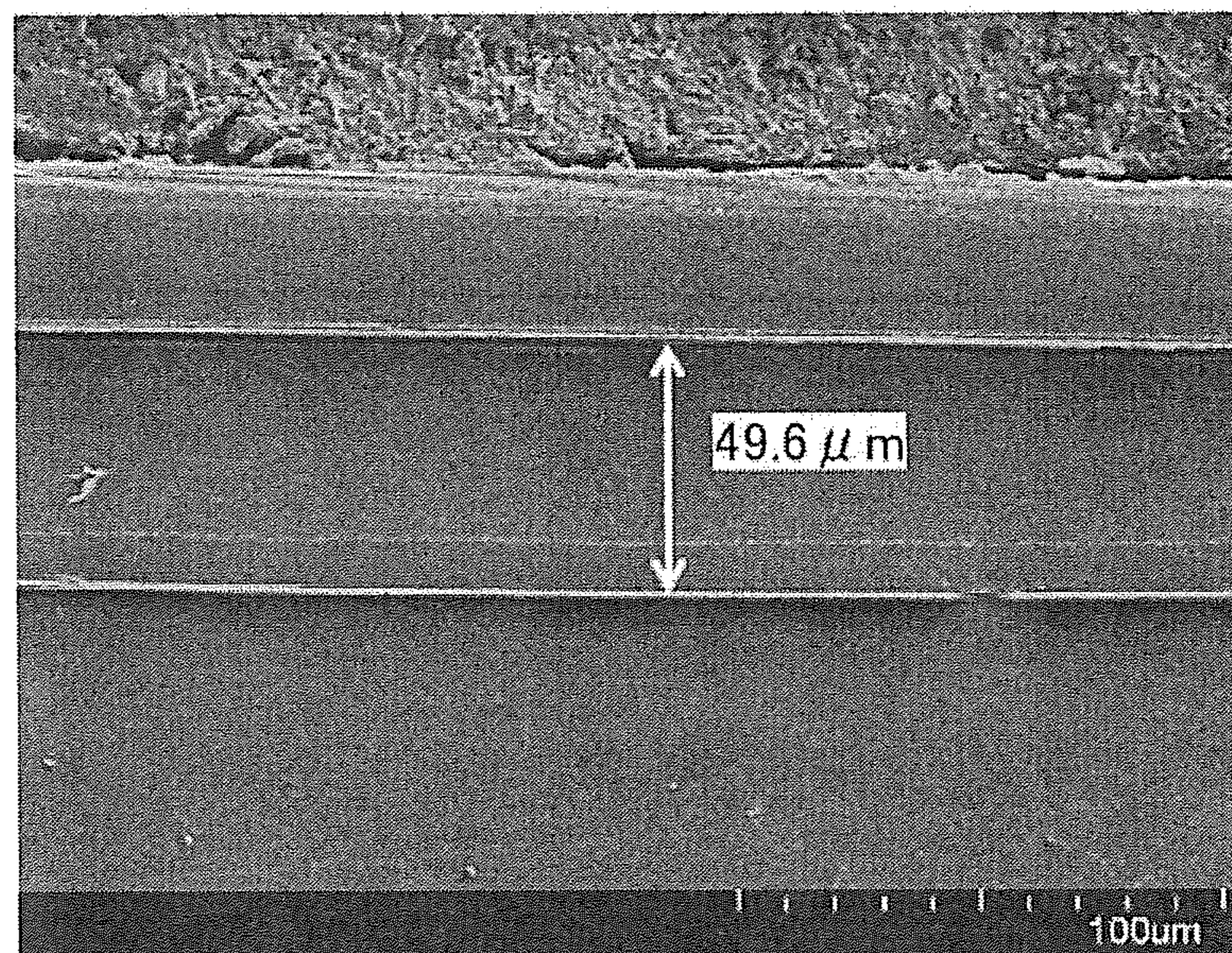


FIG. 44B



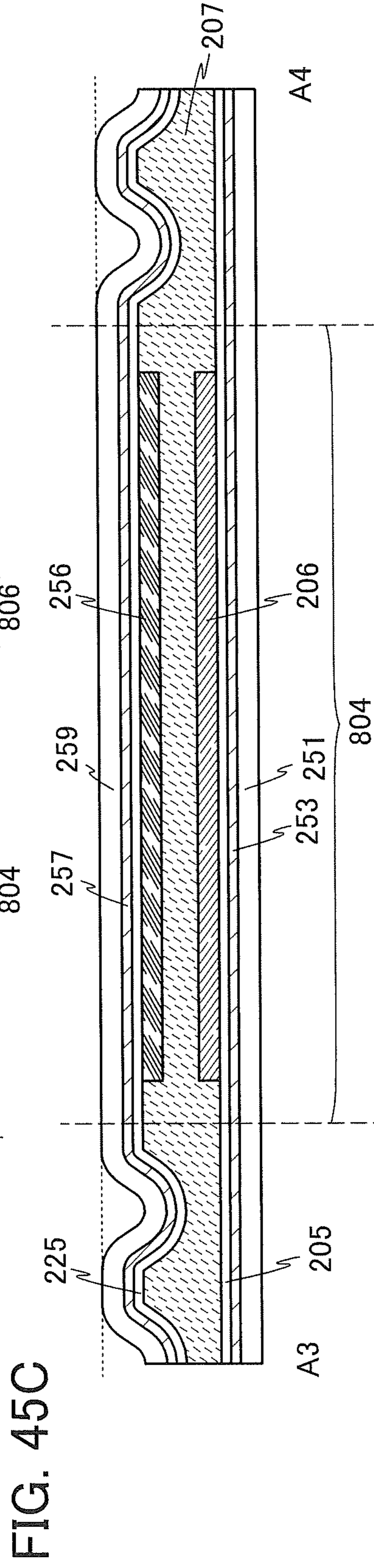
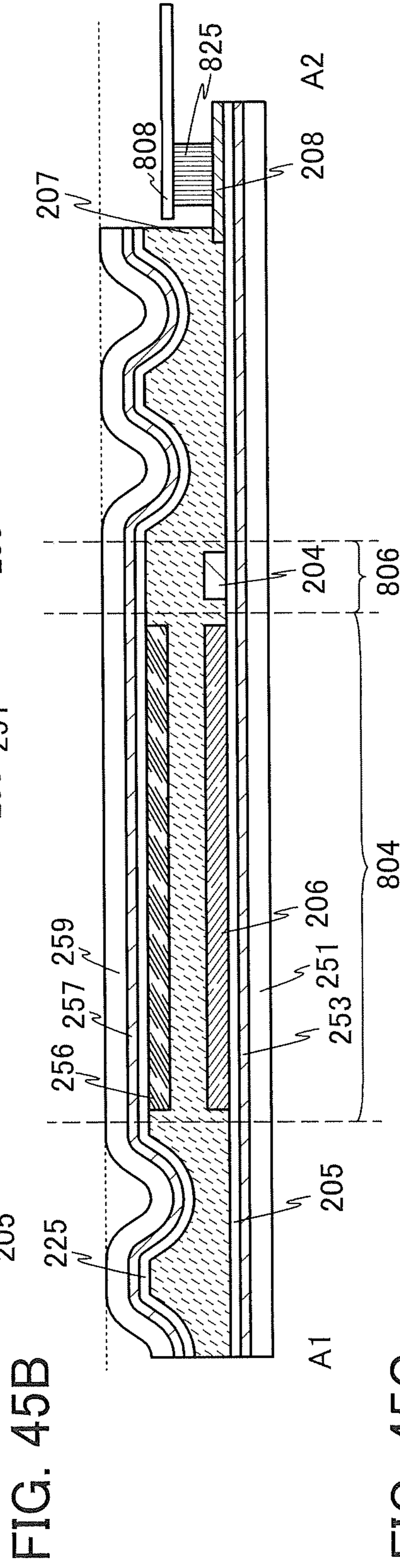
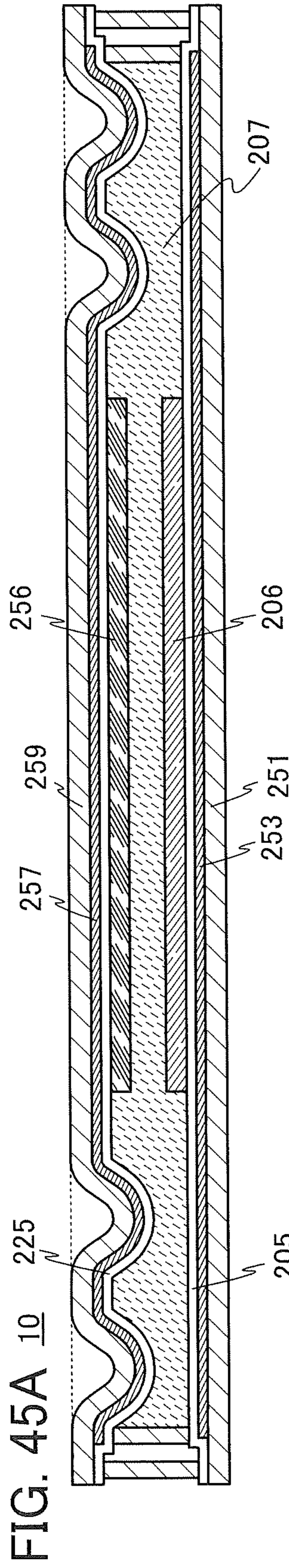




FIG. 46A

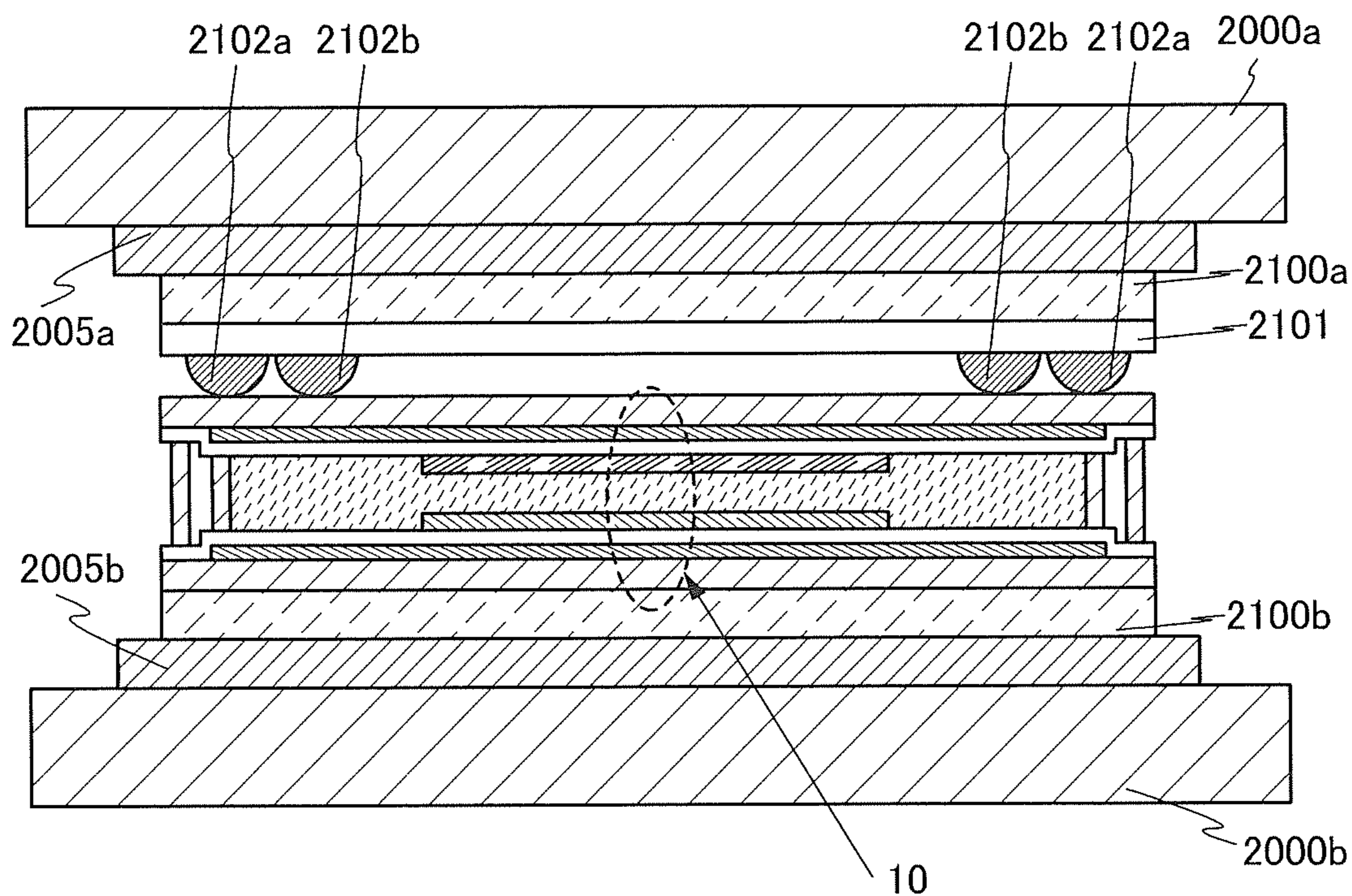


FIG. 46B

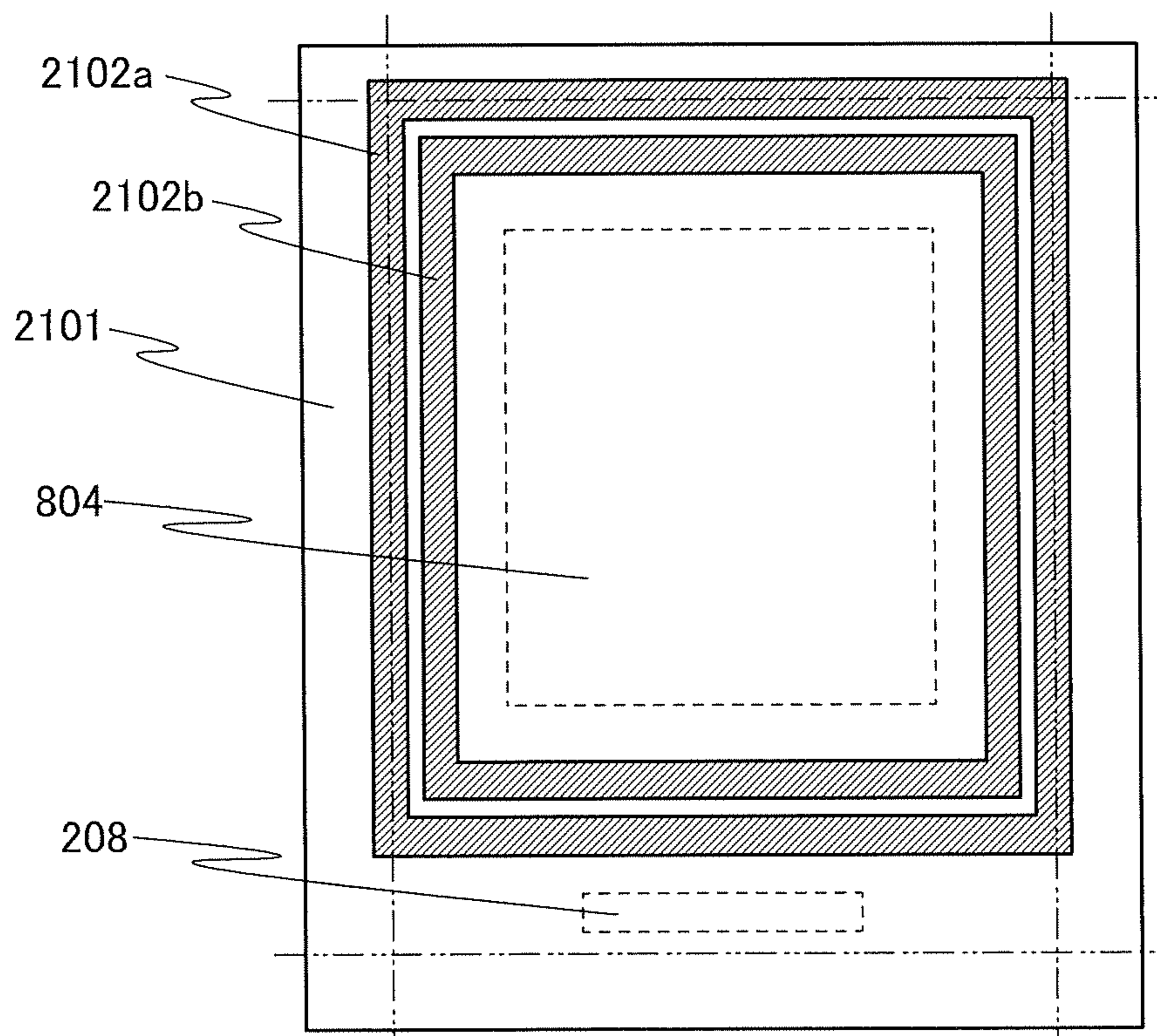


FIG. 47A

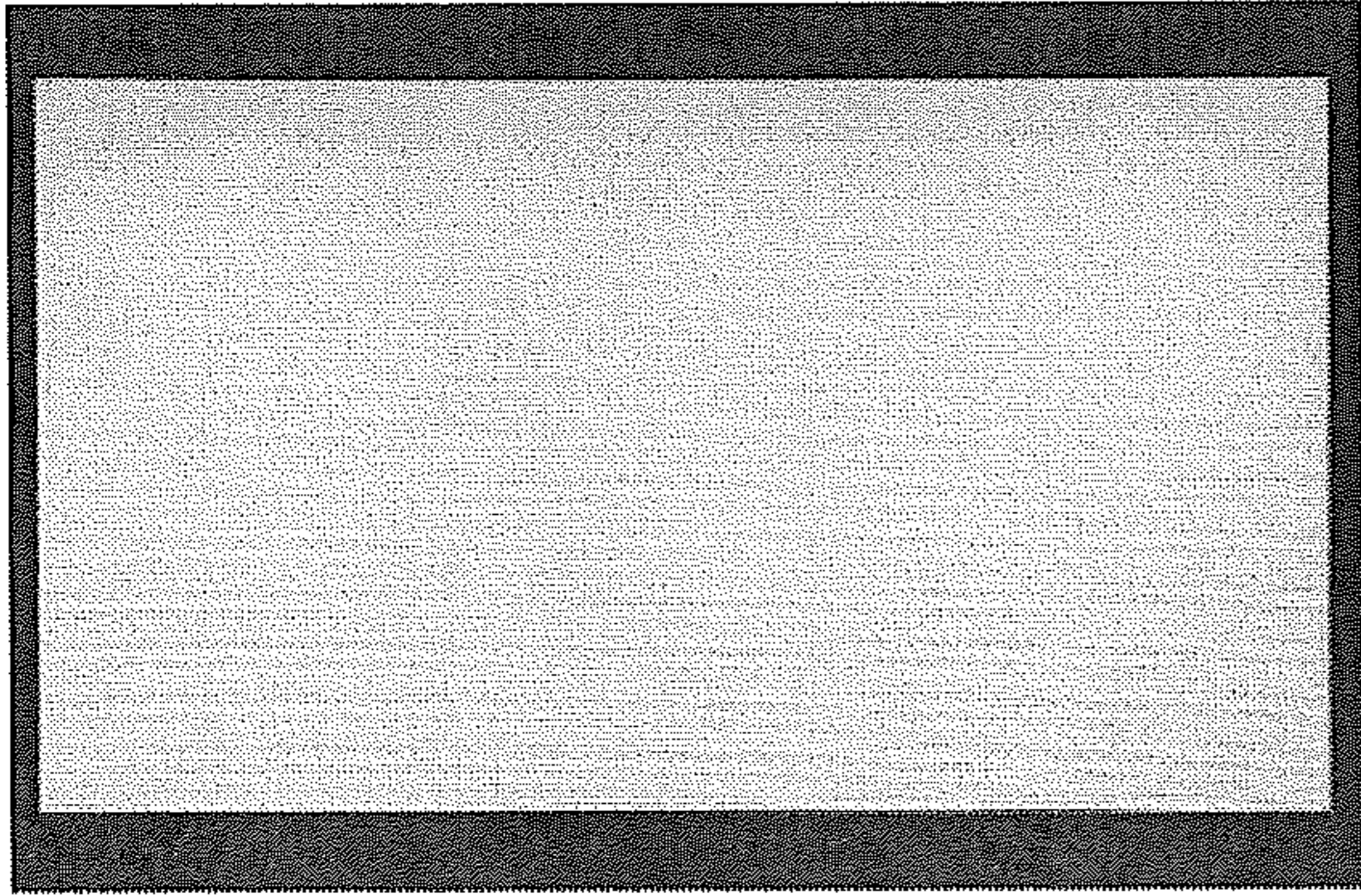


FIG. 47B

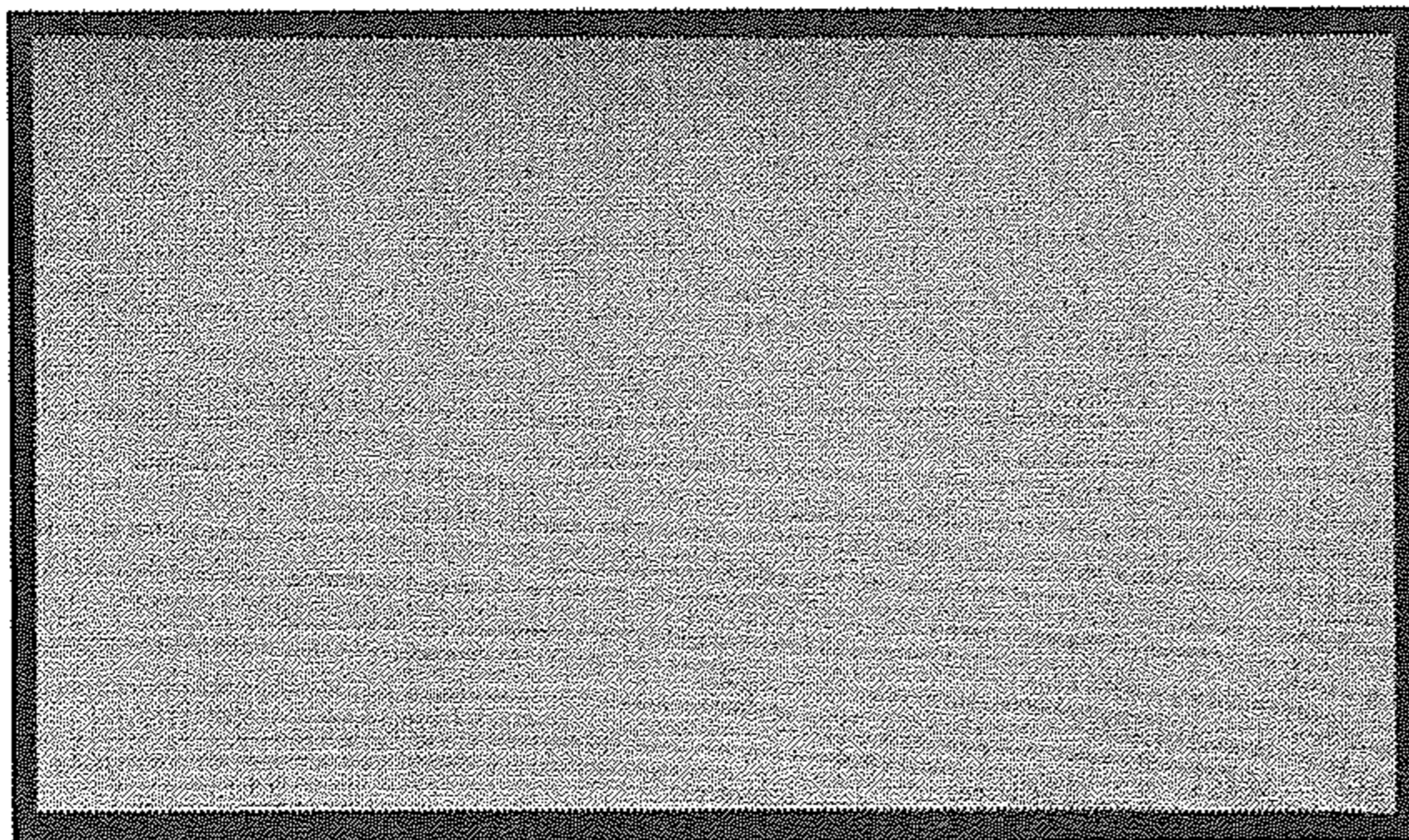


FIG. 47C

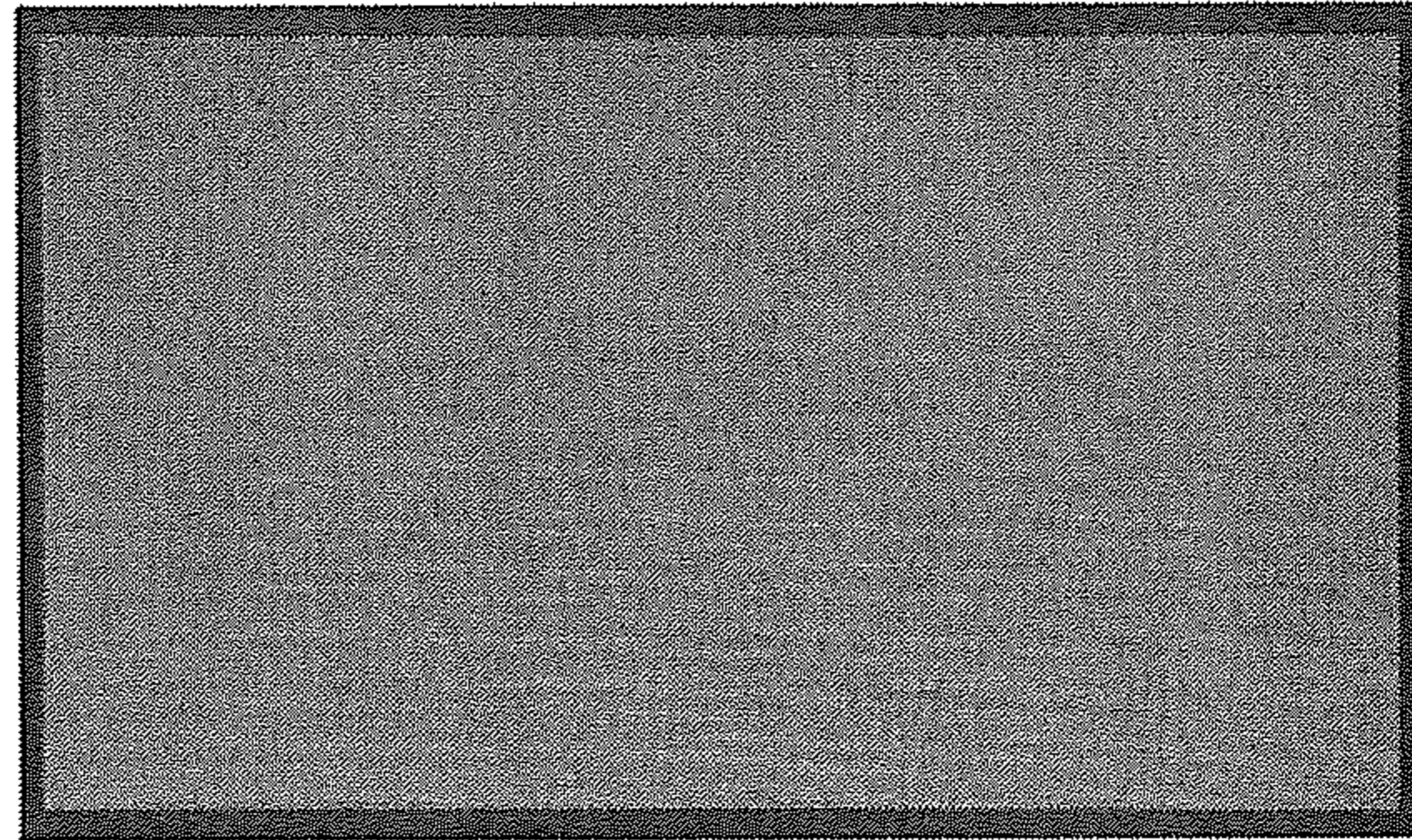


FIG. 47D

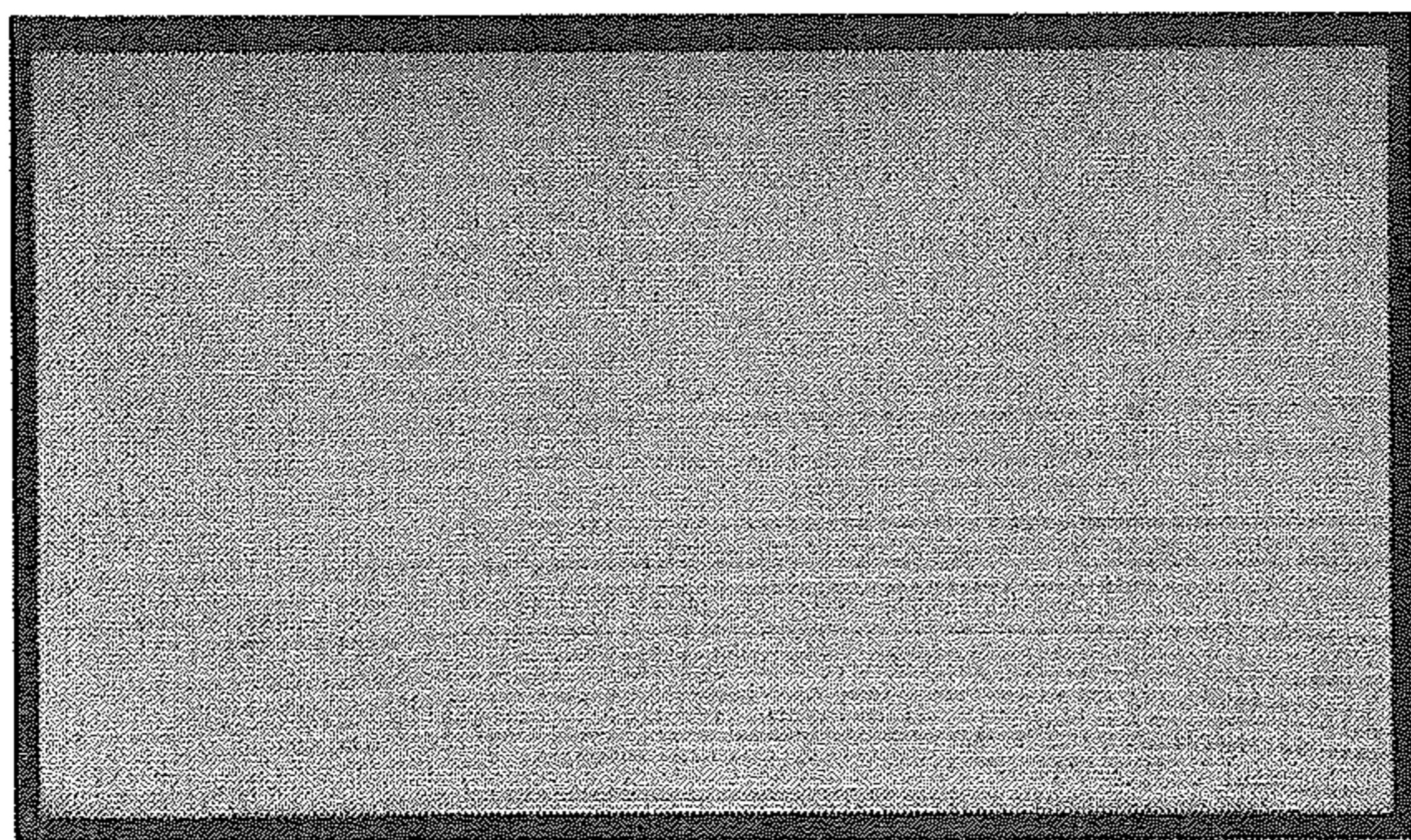
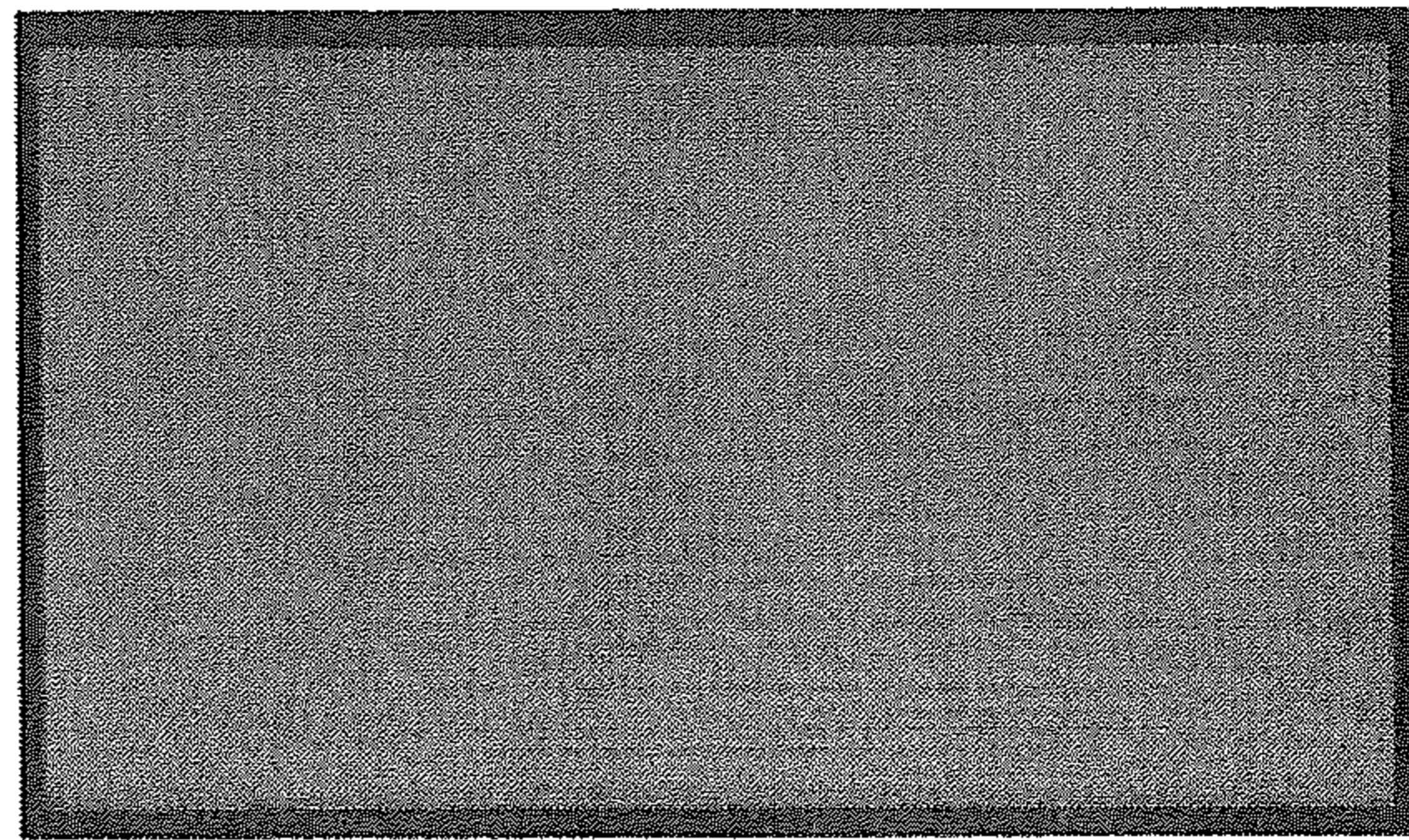


FIG. 47E



**LIGHT-EMITTING DEVICE, MODULE,  
ELECTRONIC DEVICE, AND METHOD FOR  
MANUFACTURING LIGHT-EMITTING  
DEVICE**

This application is a continuation of copending U.S. application Ser. No. 16/192,066, filed on Nov. 15, 2018 which is a continuation of U.S. application Ser. No. 15/839,059, filed on Dec. 12, 2017 (now U.S. Pat. No. 10,270,057 issued Apr. 23, 2019) which is a continuation of U.S. application Ser. No. 14/882,918, filed on Oct. 14, 2015 (now U.S. Pat. No. 9,847,505 issued Dec. 19, 2017) which are all incorporated herein by reference.

TECHNICAL FIELD

One embodiment of the present invention relates to a light-emitting device, a module, an electronic device, and a manufacturing method thereof. In particular, one embodiment of the present invention relates to a light-emitting device utilizing organic electroluminescence (EL), and a manufacturing method thereof.

Note that one embodiment of the present invention is not limited to the above technical field. Examples of the technical field of one embodiment of the present invention include a semiconductor device, a display device, a light-emitting device, a power storage device, a memory device, an electronic device, a lighting device, an input device (e.g., a touch sensor), an input-output device (e.g., a touch panel), a driving method thereof, and a manufacturing method thereof.

BACKGROUND ART

Recent light-emitting devices and display devices are expected to be applied to a variety of uses and become diversified.

For example, light-emitting devices and display devices for mobile devices and the like are required to be thin, lightweight, and less likely to be broken.

Light-emitting elements utilizing EL (also referred to as EL elements) have features such as ease of thinning and lightening, high-speed response to an input signal, and driving with a direct-current low voltage source; therefore, application of the light-emitting elements to light-emitting devices and display devices has been proposed.

For example, Patent Document 1 discloses a flexible active matrix light-emitting device in which an organic EL element or a transistor serving as a switching element is provided over a film substrate.

An organic EL element has a problem in that entry of impurities such as moisture or oxygen from the outside erodes the reliability.

When impurities such as moisture or oxygen enter an organic compound or a metal material contained in an organic EL element from the outside of the organic EL element, the lifetime of the organic EL element is significantly shortened in some cases. This is because an organic compound or a metal material contained in the organic EL element reacts with the impurities such as moisture or oxygen and thus deteriorates.

Thus, a technique to seal an organic EL element for preventing entry of impurities has been researched and developed.

REFERENCE

Patent Document

5 [Patent Document 1] Japanese Published Patent Application No. 2003-174153

DISCLOSURE OF INVENTION

10 An object of one embodiment of the present invention is to provide a highly reliable light-emitting device, display device, electronic device, or lighting device. Alternatively, an object of one embodiment of the present invention is to provide a highly reliable flexible light-emitting device,  
15 display device, electronic device, or lighting device.

An object of one embodiment of the present invention is to provide a novel light-emitting device, display device, electronic device, or lighting device. Alternatively, an object of one embodiment of the present invention is to provide a  
20 lightweight light-emitting device, display device, electronic device, or lighting device. Alternatively, an object of one embodiment of the present invention is to provide a light-emitting device, display device, electronic device, or lighting device that is less likely to be broken. Alternatively, an  
25 object of one embodiment of the present invention is to provide a thin light-emitting device, display device, electronic device, or lighting device.

Note that the description of these objects does not disturb the existence of other objects. In one embodiment of the  
30 present invention, there is no need to achieve all the objects. Other objects can be derived from the description of the specification, the drawings, and the claims.

One embodiment of the present invention is a light-emitting device including a light-emitting portion and a  
35 non-light-emitting portion. The non-light-emitting portion is provided outside the light-emitting portion to have a frame-like shape. The non-light-emitting portion includes a portion whose thickness is smaller than that of the light-emitting portion. The non-light-emitting portion may include a first  
40 portion and a second portion. The first portion is closer to the light-emitting portion than the second portion is, and has a thickness smaller than that of the second portion.

One embodiment of the present invention is a light-emitting device including a light-emitting portion and a  
45 non-light-emitting portion. The non-light-emitting portion is provided outside the light-emitting portion to have a frame-like shape. The non-light-emitting portion includes a portion whose thickness decreases continuously from the light-emitting portion side to an end portion of the light-emitting  
50 device. The non-light-emitting portion may include a first portion and a second portion. The first portion is closer to the light-emitting portion than the second portion is. The thickness of the first portion decreases from the light-emitting portion side to the end portion side of the light-emitting  
55 device. The thickness of the second portion increases from the light-emitting portion side to the end portion of the light-emitting device.

The light-emitting device preferably has flexibility.

The light-emitting portion may include a light-emitting  
60 element and a transistor. The transistor is electrically connected to the light-emitting element. The light-emitting element is preferably an organic EL element.

The non-light-emitting portion may include at least one of a signal line driver circuit and a scan line driver circuit.

65 One embodiment of the present invention is a light-emitting device including a light-emitting portion and a non-light-emitting portion. The light-emitting portion

includes a first flexible substrate, a second flexible substrate, a first bonding layer, a second bonding layer, a first insulating layer, and a first functional layer. The non-light-emitting portion includes the first flexible substrate, the second flexible substrate, the first bonding layer, the second bonding layer, and the first insulating layer. The first bonding layer is positioned between the first flexible substrate and the first insulating layer. The second bonding layer is positioned between the second flexible substrate and the first insulating layer. The first functional layer is positioned between the second bonding layer and the first insulating layer. The first bonding layer and the second bonding layer partly overlap with each other with the first insulating layer provided therebetween. The first functional layer includes a light-emitting element. A gap between the first flexible substrate and the second flexible substrate is smaller in at least part of the non-light-emitting portion than in the light-emitting portion. The non-light-emitting portion may include a first portion and a second portion. The first portion is closer to the light-emitting portion than the second portion is. The gap between the first flexible substrate and the second flexible substrate is smaller in the first portion than in the second portion.

The gap between the first flexible substrate and the second flexible substrate may be smaller or larger in the second portion than in the light-emitting portion, or may be the same in the second portion and the light-emitting portion.

The first portion may be provided outside the light-emitting portion to have a frame-like shape. The second portion may be provided outside the first portion to have a frame-like shape.

In each of the above structures, the light-emitting portion may include a third bonding layer, a second insulating layer, and a second functional layer. The non-light-emitting portion may include the third bonding layer and the second insulating layer. The third bonding layer may be positioned between the second bonding layer and the first insulating layer. The second insulating layer may be positioned between the second bonding layer and the third bonding layer. The first functional layer and the second functional layer may partly overlap with each other with the third bonding layer provided therebetween. The second functional layer may include a coloring layer.

The thickness of the third bonding layer is preferably smaller in the non-light-emitting portion than in the light-emitting portion. The light-emitting portion includes a third portion and the non-light-emitting portion includes a fourth portion. The thickness of the third bonding layer in the fourth portion is smaller than the thickness of the third bonding layer in the third portion. The thickness of the third bonding layer in the fourth portion is preferably half the thickness of the third bonding layer in the third portion, further preferably one third the thickness of the third bonding layer in the third portion. Specifically, the thickness of the third bonding layer in the fourth portion is greater than or equal to 0.1  $\mu\text{m}$  and less than or equal to 10  $\mu\text{m}$ , preferably greater than or equal to 0.1  $\mu\text{m}$  and less than or equal to 5  $\mu\text{m}$ , further preferably greater than or equal to 0.1  $\mu\text{m}$  and less than or equal to 3  $\mu\text{m}$ .

It is preferable that the thickness of the first flexible substrate be the same in the light-emitting portion and the non-light-emitting portion, and the thickness of the second flexible substrate be the same in the light-emitting portion and the non-light-emitting portion. In one embodiment of the present invention, the flexible substrates are attached to each other after a portion thinner than the light-emitting portion is formed in the non-light-emitting portion. Thus, it

is possible to prevent expansion and contraction of the flexible substrates due to force applied thereto.

One embodiment of the present invention also includes a display device, a semiconductor device, and an input-output device to which any of the above structures is applied. These devices differ in the functional element included in the functional layer. For example, the display device of one embodiment of the present invention includes a display element as the functional element. The semiconductor device of one embodiment of the present invention includes a semiconductor element as the functional element. The input-output device of one embodiment of the present invention includes a light-emitting element or a display element, and a touch sensor as the functional elements.

One embodiment of the present invention is a module including a light-emitting device, a display device, a semiconductor device, or an input-output device to which any of the above structures is applied. The module is provided with a connector such as a flexible printed circuit (FPC) or a tape carrier package (TCP) or is mounted with an integrated circuit (IC) by a chip on glass (COG) method or the like.

One embodiment of the present invention is an electronic device or a lighting device including the above module. For example, one embodiment of the present invention is an electronic device including the module and any of an antenna, a battery, a housing, a speaker, a microphone, an operation switch, and an operation button.

One embodiment of the present invention is a manufacturing method of a light-emitting device that includes first to fourth steps (hereinafter referred to as a manufacturing method A). The first step includes a step of forming a light-emitting element over a first substrate. The second step includes a step of forming a bonding layer and a partition over the first substrate or a second substrate. The third step includes a step of making the first substrate and the second substrate overlap with each other under a first atmosphere to position the light-emitting element in a space surrounded by the partition, the first substrate, and the second substrate. The fourth step includes a step of curing the bonding layer and the partition under a second atmosphere. The first atmosphere has a lower pressure than the second atmosphere. In the second step, the partition is formed to surround the bonding layer with a gap left between the partition and the bonding layer.

One embodiment of the present invention is a manufacturing method of a light-emitting device that includes first to sixth steps (hereinafter referred to as a manufacturing method B). The first step includes a step of forming a separation layer over a first substrate. The second step includes a step of forming a layer to be separated over the separation layer. In the second step, an insulating layer over the separation layer and a light-emitting element over the insulating layer are formed as the layer to be separated. The third step includes a step of forming a bonding layer and a partition over the first substrate or a second substrate. In the third step, the bonding layer is formed to overlap with the separation layer and the layer to be separated. In the third step, the partition is formed to surround the bonding layer with a gap left between the partition and the bonding layer. The fourth step includes a step of making the first substrate and the second substrate overlap with each other under a first atmosphere to position the light-emitting element in a space surrounded by the partition, the first substrate, and the second substrate. The fifth step includes a step of curing the bonding layer under a second atmosphere. The sixth step

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includes a step of separating the first substrate and the layer to be separated. The first atmosphere has a lower pressure than the second atmosphere.

In the fifth step of the manufacturing method B, the partition is preferably cured before the bonding layer is cured or in the step of curing the bonding layer.

In the manufacturing methods A and B, the first atmosphere may be a reduced-pressure atmosphere and the second atmosphere may be an air atmosphere or a pressurized atmosphere.

One embodiment of the present invention is a manufacturing method of a light-emitting device that includes first to fifth steps (hereinafter referred to as a manufacturing method C). The first step includes a step of forming a light-emitting element over a first substrate. The second step includes a step of forming a bonding layer over the first substrate or a second substrate. The third step includes a step of making the first substrate and the second substrate overlap with each other to surround the light-emitting element with the bonding layer, the first substrate, and the second substrate. The fourth step includes a step of applying pressure to the bonding layer with a member having a projection. The fifth step includes a step of curing the bonding layer.

In the manufacturing method C, the fourth step and the fifth step are preferably performed at the same time.

In the manufacturing method C, the second step may include a step of forming a partition over the first substrate or the second substrate. The partition is formed to surround the bonding layer. A step of curing the partition is preferably performed between the third step and the fourth step.

One embodiment of the present invention is a manufacturing method of a light-emitting device that includes first to seventh steps (hereinafter referred to as a manufacturing method D). The first step includes a step of forming a separation layer over a first substrate. The second step includes a step of forming a layer to be separated over the separation layer. In the second step, an insulating layer over the separation layer and a light-emitting element over the insulating layer are formed as the layer to be separated. The third step includes a step of forming a bonding layer over the first substrate or a second substrate. In the third step, the bonding layer is formed to overlap with the separation layer and the layer to be separated. The fourth step includes a step of making the first substrate and the second substrate overlap with each other to surround the light-emitting element with the bonding layer, the first substrate, and the second substrate. The fifth step includes a step of applying pressure to the bonding layer with a member having a projection. The sixth step includes a step of curing the bonding layer. The seventh step includes a step of separating the first substrate and the layer to be separated.

In the manufacturing method D, the fifth step and the sixth step are preferably performed at the same time.

In the manufacturing method D, the third step may include a step of forming a partition over the first substrate or the second substrate. The partition is formed to surround the bonding layer. A step of curing the partition is preferably performed between the fourth step and the fifth step.

One embodiment of the present invention can provide a highly reliable flexible light-emitting device, display device, electronic device, or lighting device.

One embodiment of the present invention can provide a novel light-emitting device, display device, electronic device, or lighting device. One embodiment of the present invention can provide a lightweight light-emitting device, display device, electronic device, or lighting device. One embodiment of the present invention can provide a light-

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emitting device, display device, electronic device, or lighting device that is less likely to be broken. One embodiment of the present invention can provide a thin light-emitting device, display device, electronic device, or lighting device.

Note that the description of these effects does not disturb the existence of other effects. One embodiment of the present invention does not necessarily achieve all the effects listed above. Other effects can be derived from the description of the specification, the drawings, and the claims.

#### BRIEF DESCRIPTION OF DRAWINGS

FIGS. 1A to 1D illustrate examples of a light-emitting device.

FIGS. 2A to 2D illustrate examples of a light-emitting device.

FIGS. 3A to 3F illustrate examples of a light-emitting device.

FIGS. 4A to 4D illustrate examples of a light-emitting device.

FIGS. 5A to 5E illustrate an example of a method for manufacturing a light-emitting device.

FIGS. 6A and 6B illustrate an example of a method for manufacturing a light-emitting device.

FIGS. 7A and 7B illustrate an example of a method for manufacturing a light-emitting device.

FIGS. 8A to 8D illustrate an example of a method for manufacturing a light-emitting device.

FIGS. 9A to 9D illustrate an example of a method for manufacturing a light-emitting device.

FIGS. 10A and 10B illustrate an example of a method for manufacturing a light-emitting device.

FIGS. 11A to 11C illustrate an example of a light-emitting device.

FIGS. 12A to 12D illustrate examples of a light-emitting device.

FIGS. 13A to 13D illustrate examples of a light-emitting device.

FIGS. 14A and 14B illustrate an example of a light-emitting device.

FIGS. 15A to 15D illustrate examples of a light-emitting device.

FIGS. 16A to 16D illustrate examples of a light-emitting device.

FIGS. 17A to 17C illustrate an example of a light-emitting device.

FIGS. 18A to 18D illustrate examples of a light-emitting device.

FIGS. 19A to 19D illustrate examples of a method for manufacturing a light-emitting device.

FIGS. 20A to 20D illustrate an example of a method for manufacturing a light-emitting device.

FIGS. 21A to 21D illustrate an example of a method for manufacturing a light-emitting device.

FIGS. 22A to 22D illustrate an example of a method for manufacturing a light-emitting device.

FIGS. 23A1, 23A2, 23B1, 23B2, and 23C illustrate examples of a light-emitting device.

FIGS. 24A and 24B illustrate an example of a light-emitting device.

FIGS. 25A and 25B illustrate an example of a light-emitting device.

FIGS. 26A to 26D illustrate examples of a light-emitting device.

FIGS. 27A and 27B illustrate examples of a light-emitting device.

FIG. 28 illustrates an example of a light-emitting device.

FIGS. 29A and 29B illustrate examples of a light-emitting device.

FIGS. 30A and 30B illustrate examples of a light-emitting device.

FIGS. 31A and 31B illustrate examples of a light-emitting device.

FIG. 32 illustrates an example of a light-emitting device.

FIGS. 33A to 33C illustrate an example of a light-emitting device.

FIGS. 34A and 34B illustrate an example of an input-output device.

FIGS. 35A and 35B illustrate examples of an input-output device.

FIGS. 36A to 36C illustrate examples of an input-output device.

FIGS. 37A to 37C illustrate examples of an input-output device.

FIGS. 38A, 38B, 38C1, 38C2, 38D, 38E, 38F, 38G, and 38H illustrate examples of an electronic device and a lighting device.

FIGS. 39A1, 39A2, and 39B to 39I illustrate examples of an electronic device.

FIGS. 40A to 40E illustrate examples of an electronic device.

FIGS. 41A to 41C illustrate methods for manufacturing a sample of Example 1.

FIGS. 42A and 42B are photographs showing results of Example 1.

FIGS. 43A to 43C are photographs of observed cross sections of a light-emitting device of Example 2.

FIGS. 44A and 44B are photographs of observed cross sections of a light-emitting device of Example 2.

FIGS. 45A to 45C illustrate a light-emitting device of Example 3 and a manufacturing method thereof.

FIGS. 46A and 46B illustrate a method for manufacturing a light-emitting device of Example 3.

FIGS. 47A to 47E are photographs showing light emission by a light-emitting device of Example 3.

#### BEST MODE FOR CARRYING OUT THE INVENTION

Embodiments will be described in detail with reference to the accompanying drawings. Note that the present invention is not limited to the description below, and it is easily understood by those skilled in the art that various changes and modifications can be made without departing from the spirit and scope of the present invention. Therefore, the present invention should not be construed as being limited to the description in the following embodiments.

Note that in the structures of the invention described below, the same portions or portions having similar functions are denoted by the same reference numerals in different drawings, and description of such portions is not repeated. The same hatching pattern is applied to portions having similar functions, and the portions are not especially denoted by reference numerals in some cases.

The position, size, range, or the like of each structure illustrated in drawings is not accurately represented in some cases for easy understanding. Therefore, the disclosed invention is not necessarily limited to the position, size, range, or the like disclosed in the drawings.

The terms “film” and “layer” can be interchanged with each other according to circumstances. For example, the term “conductive layer” can be changed into the term

“conductive film.” Furthermore, the term “insulating film” can be changed into the term “insulating layer.”

#### Embodiment 1

In this embodiment, a light-emitting device of one embodiment of the present invention and a manufacturing method thereof will be described with reference to FIGS. 1A to 1D, FIGS. 2A to 2D, FIGS. 3A to 3F, FIGS. 4A to 4D, FIGS. 5A to 5E, FIGS. 6A and 6B, FIGS. 7A and 7B, FIGS. 8A to 8D, FIGS. 9A to 9D, FIGS. 10A and 10B, FIGS. 11A to 11C, FIGS. 12A to 12D, FIGS. 13A to 13D, FIGS. 14A and 14B, FIGS. 15A to 15D, FIGS. 16A to 16D, FIGS. 17A to 17C, FIGS. 18A to 18D, FIGS. 19A to 19D, FIGS. 20A to 20D, FIGS. 21A to 21D, FIGS. 22A to 22D, and FIGS. 23A1, 23A2, 23B1, 23B2, and 23C.

Although light-emitting devices including organic EL elements are mainly described as examples in this embodiment, one embodiment of the present invention is not limited to these examples. A light-emitting device or a display device including another light-emitting element or display element which will be described in Embodiment 2 as an example is also one embodiment of the present invention. Moreover, one embodiment of the present invention is not limited to the light-emitting device or the display device and can be applied to a variety of devices such as a semiconductor device and an input-output device.

In some cases, a functional element (e.g., a light-emitting element or a transistor) included in a light-emitting device deteriorates because of entry of impurities such as moisture from the outside, which might reduce the reliability. Entry of impurities in the thickness direction of the light-emitting device (i.e., entry through a light-emitting surface and a surface facing the light-emitting surface) can be minimized by providing the functional element between a pair of layers (substrates, insulating films, or the like) with a high gas barrier property. At a side surface of the light-emitting device, a bonding layer for sealing the light-emitting element or the transistor is exposed to the air. When a resin is used for the bonding layer, for example, it is possible to achieve higher impact resistance, higher heat resistance, and greater robustness against deformation due to external force or the like than when a glass frit or the like is used. On the other hand, a resin has an insufficient gas barrier property, water-resistant property, or moisture-resistant property in some cases.

In view of the above, in the light-emitting device of one embodiment of the present invention, a non-light-emitting portion has a portion whose thickness is smaller than that of a light-emitting portion. The light-emitting device has the light-emitting portion and the non-light-emitting portion, and the non-light-emitting portion is provided outside the light-emitting portion to have a frame-like shape.

When the light-emitting device (bonding layer) has a region having a smaller thickness than other portions, impurities such as moisture entering through a side surface of the light-emitting device do not easily pass through the region. As a result, the impurities are less likely to reach the functional element than when the light-emitting device (bonding layer) has a uniform thickness, and a reduction in reliability of the light-emitting device can be inhibited.

The reliability of the light-emitting device can be improved by changing its shape (or the thickness of the bonding layer), which allows the material used for the bonding layer to be selected from a wider range of options.

The use of a resin for the bonding layer can increase the flexibility and the resistance to bending of the light-emitting device.

Note that the thinner region may be locally provided in the non-light-emitting portion. Alternatively, the thickness may decrease in a continuous (smooth) manner from the light-emitting portion side of the non-light-emitting portion to an end portion of the light-emitting device.

Two methods for manufacturing the light-emitting device of one embodiment of the present invention are described briefly.

#### Manufacturing Method a

First, a first substrate and a second substrate are prepared. Then, a light-emitting element is formed over the first substrate. After that, a bonding layer and a partition are formed over the first substrate or the second substrate. The partition is provided to surround the bonding layer and the light-emitting element, with a gap left between the partition and the bonding layer.

Then, the first substrate and the second substrate overlap with each other under a first atmosphere, so that the light-emitting element and the bonding layer are positioned in a space surrounded by the partition, the first substrate, and the second substrate. When the first atmosphere is a reduced-pressure atmosphere, for example, the space surrounded by the partition, the first substrate, and the second substrate is in a reduced-pressure state. Note that since a gap is left between the bonding layer and the partition, a hollow portion is formed in the space.

Next, the first substrate and the second substrate are exposed to a second atmosphere. When the second atmosphere is an air atmosphere, for example, the pair of substrates are subjected to atmospheric pressure. The bonding layer spreads toward an end portion of the substrate and fills the hollow portion between the partition and the bonding layer. As a result, the end portion of the light-emitting device partly has a smaller thickness than the middle portion. Note that the pressure of the second atmosphere is higher than that of the first atmosphere.

Then, the bonding layer and the partition are cured. In one embodiment of the present invention, at least one of the bonding layer and the partition is cured under an atmosphere with a pressure higher than that of the first atmosphere. It is preferable that both the bonding layer and the partition be cured under an atmosphere having a higher pressure than the first atmosphere, because a sufficiently thin portion can be provided in the light-emitting device reliably. In the above manner, the light-emitting device in which part of the non-light-emitting portion has a smaller thickness than the light-emitting portion can be manufactured.

#### Manufacturing Method b

First, a first substrate and a second substrate are prepared. Then, a light-emitting element is formed over the first substrate. After that, a bonding layer is formed over the first substrate or the second substrate.

Then, the first substrate and the second substrate overlap with each other, so that the light-emitting element is surrounded by the bonding layer, the first substrate, and the second substrate.

Before the bonding layer is completely cured, at least part of the non-light-emitting portion is subjected to pressure, whereby the non-light-emitting portion partly has a smaller thickness than the light-emitting portion.

For example, pressure can be applied to at least part of the non-light-emitting portion with the use of a third substrate having a projection. Specifically, the third substrate overlaps with the non-light-emitting portion so that the projection overlaps with the non-light-emitting portion. Then, pressure is applied to the stacked-layer structure including the first substrate, the second substrate, and the third substrate. The non-light-emitting portion in a portion that overlaps with the projection and the vicinity thereof are pressed, where the bonding layer has a smaller thickness than in other portions; thus, the non-light-emitting portion of the light-emitting device can have a first portion whose thickness is smaller than that of the light-emitting portion. Note that the non-light-emitting portion may include, outside the thin first portion, a second portion whose thickness is larger than that of the first portion. The relation between the thickness of the light-emitting device in the second portion and that in the light-emitting portion is not particularly limited; the second portion may have a larger or smaller thickness than or may have the same thickness as the light-emitting portion.

The bonding layer is cured while or after pressure is applied. By curing the bonding layer, the light-emitting element can be sealed with the bonding layer, the first substrate, and the second substrate. In the above manner, the light-emitting device in which part of the non-light-emitting portion has a smaller thickness than the light-emitting portion can be manufactured.

Examples of the structure and manufacturing method of the light-emitting device of one embodiment of the present invention are described below. First, structure examples a-1, a-2, and a-3 that can be formed by the above manufacturing method a are described. Then, detailed description of manufacturing methods of the structure examples a-2 and a-3 is made. After that, structure examples b-1, b-2, and b-3 that can be formed by the above manufacturing method b are described. Lastly, detailed description of manufacturing methods of the structure examples b-1, b-2, and b-3 is made. Note that part of a structure example or a manufacturing method similar to that of a preceding structure example or a preceding manufacturing method will not be described again.

#### Structure Example a-1

FIG. 1A is a top view of a light-emitting device. FIG. 1B is a cross-sectional view taken along a dashed-dotted line A1-A2 in FIG. 1A. FIG. 1C illustrates a modification example of FIG. 1B. FIG. 1D is a cross-sectional view taken along a dashed-dotted line A3-A4 in FIG. 1A.

The light-emitting device illustrated in FIG. 1A includes a light-emitting portion **804** and a driver circuit portion **806**. Portions other than the light-emitting portion **804** in the light-emitting device can be regarded as non-light-emitting portions. In other words, the non-light-emitting portion is provided outside the light-emitting portion **804** to have a frame-like shape. For example, the driver circuit portion **806** is a non-light-emitting portion.

The light-emitting device in FIGS. 1A to 1D includes a substrate **251**, a functional layer **204**, a functional layer **206**, a bonding layer **207**, a conductive layer **208**, and a substrate **259**.

In the light-emitting portion **804**, the functional layer **206** is provided over the substrate **251**.

The functional layer **206** includes a light-emitting element and may also include a transistor, a capacitor, or the like.

As the light-emitting element, a self-luminous element can be used, and an element whose luminance is controlled

by current or voltage is included in the category of the light-emitting element. For example, a light-emitting diode (LED), an organic EL element, an inorganic EL element, or the like can be used. The light-emitting element may have any of a top emission structure, a bottom emission structure, and a dual emission structure.

In the driver circuit portion **806**, the functional layer **204** is provided over the substrate **251**.

The functional layer **204** includes a transistor and may also include a capacitor, a resistor, a switch element, or the like. The light-emitting device of one embodiment of the present invention may include at least one of a signal line driver circuit and a scan line driver circuit as a driver circuit portion. The light-emitting device of one embodiment of the present invention does not necessarily include a driver circuit portion.

The conductive layer **208** is electrically connected to an external input terminal through which a signal (e.g., a video signal, a clock signal, a start signal, or a reset signal) or a potential from the outside is transmitted to the driver circuit portion **806**. In FIGS. **1B** and **1C**, the conductive layer **208** is electrically connected to an FPC **808** through a connector **825**.

The substrate **251** and the substrate **259** are attached to each other with the bonding layer **207**.

For each of the substrates, a material such as glass, quartz, an organic resin, a metal, or an alloy can be used. The substrate on the side from which light from the light-emitting element is extracted is formed using a material which transmits the light.

A flexible substrate may be used. For example, an organic resin; or glass, a metal, or an alloy that is thin enough to have flexibility can be used.

An organic resin, which has a specific gravity smaller than that of glass, is preferably used for the flexible substrate, in which case the light-emitting device can be lightweight as compared with the case where glass is used.

The substrate is preferably formed using a material with high toughness. In that case, a robust light-emitting device with high impact resistance can be provided. For example, when an organic resin substrate or a thin metal or alloy substrate is used, the light-emitting device can be lightweight and robust as compared with the case where a glass substrate is used.

A metal material and an alloy material, which have high thermal conductivity, are preferable because they can easily conduct heat to the whole substrate and accordingly can prevent a local temperature rise in the light-emitting device. The thickness of a substrate using a metal material or an alloy material is preferably greater than or equal to 10  $\mu\text{m}$  and less than or equal to 200  $\mu\text{m}$ , further preferably greater than or equal to 20  $\mu\text{m}$  and less than or equal to 50  $\mu\text{m}$ .

There is no particular limitation on a material of the metal substrate or the alloy substrate, but it is preferable to use, for example, aluminum, copper, nickel, or a metal alloy such as an aluminum alloy or stainless steel.

When a material with high thermal emissivity is used for the substrate, the surface temperature of the light-emitting device can be prevented from rising, leading to inhibition of breakage or a decrease in reliability of the light-emitting device. For example, the substrate may have a stacked-layer structure of a metal substrate and a layer with high thermal emissivity (the layer can be formed using a metal oxide or a ceramic material, for example).

Examples of a material having flexibility and a light-transmitting property include polyester resins such as poly(ethylene terephthalate) (PET) and poly(ethylene naphtha-

late) (PEN), a polyacrylonitrile resin, a polyimide resin, a poly(methyl methacrylate) resin, a polycarbonate (PC) resin, a polyethersulfone (PES) resin, a polyamide resin (e.g., nylon or aramid), a polycycloolefin resin, a polystyrene resin, a poly(amide imide) resin, a poly(vinyl chloride) resin, and a polytetrafluoroethylene (PTFE) resin. In particular, a material having a low coefficient of linear expansion is preferable, and for example, a poly(amide imide) resin, a polyimide resin, a polyamide resin, or PET can be suitably used. A substrate in which a fibrous body is impregnated with a resin (also referred to as prepreg) or a substrate whose coefficient of linear expansion is reduced by mixing an inorganic filler with an organic resin can also be used.

Furthermore, for the substrate, a transparent nonwoven fabric formed by processing pulp into a continuous sheet, a sheet including an artificial spider's thread fiber containing protein called fibroin, a complex in which the transparent nonwoven fabric or the sheet and a resin are mixed, a stack including a resin film and a nonwoven fabric containing a cellulose fiber whose fiber width is 4 nm or more and 100 nm or less, or a stack including a resin film and a sheet including an artificial spider's thread fiber may be used.

As shown in FIGS. **1B** to **1D**, the thickness of the light-emitting device (or the bonding layer **207**) is uniform (or substantially uniform) in the light-emitting portion **804**. Meanwhile, the non-light-emitting portion has a region with a small thickness. In other words, a gap between the substrate **251** and the substrate **259** in part of the non-light-emitting portion is smaller than that in the light-emitting portion **804**. When the thickness of an end portion of the light-emitting device is smaller than that of the light-emitting portion **804** or the like as described above, entry of impurities such as moisture and oxygen into the light-emitting device can be inhibited.

Note that FIG. **1B** illustrates an example in which the non-light-emitting portion in a portion where the driver circuit portion **806** and the conductive layer **208** are provided does not have a region whose thickness is smaller than that of the light-emitting portion. The shortest distance from the side of the light-emitting portion **804** that is adjacent to the driver circuit portion **806** to an end portion of the light-emitting device is longer than the shortest distance from the other sides of the light-emitting portion **804** to other end portions of the light-emitting device; therefore, on the side of the light-emitting device on which the driver circuit portion **806** is provided, impurities are unlikely to reach the light-emitting element or the like. In that case, the non-light-emitting portion does not necessarily have a portion whose thickness is smaller than that of the light-emitting portion. In the above manner, the element included in the driver circuit portion **806** can be prevented from deteriorating because of bending. Moreover, the conductive layer **208** and the FPC **808** can be electrically connected to each other reliably. In one embodiment of the present invention, a portion that is thinner than the light-emitting portion and has a frame-like shape may be provided in the non-light-emitting portion. FIG. **1C** illustrates an example in which the non-light-emitting portion in a portion where the driver circuit portion **806** and the conductive layer **208** are provided also has a region whose thickness is smaller than that of the light-emitting portion.

Note that as in FIGS. **2A** and **2B**, which are the cross-sectional view taken along the dashed-dotted line **A1-A2** in FIG. **1A** and that taken along the dashed-dotted line **A3-A4**, the non-light-emitting portion may have a region whose thickness is smaller than that of the light-emitting device, on two of the four sides of the light-emitting device.



Furthermore, as in FIGS. 2C and 2D, which are the cross-sectional view taken along the dashed-dotted line A1-A2 in FIG. 1A and that taken along the dashed-dotted line A3-A4, the non-light-emitting portion may have a region whose thickness is smaller than that of the light-emitting portion, on one of the four sides of the light-emitting device.

Although the functional layer 206 is formed directly over the substrate 251 in the structure example a-1, one embodiment of the present invention is not limited to this structure. As described in the following structure examples a-2 and a-3, the functional layer 206 that has been formed over a formation substrate may be transferred to the substrate 251. With this method, for example, a layer to be separated which is formed over a formation substrate having high heat resistance can be transferred to a substrate having low heat resistance, and the manufacturing temperature of the layer to be separated is not limited by the substrate having low heat resistance. The layer to be separated can be transferred to a substrate or the like that is more lightweight or flexible or thinner than the formation substrate, whereby a reduction in thickness and weight and improvement in flexibility of the light-emitting device can be achieved.

#### Structure Example a-2

FIG. 3A is a cross-sectional view taken along the dashed-dotted line A1-A2 in FIG. 1A. FIG. 3B is a cross-sectional view taken along the dashed-dotted line A3-A4 in FIG. 1A.

The light-emitting device in FIGS. 3A and 3B includes the substrate 251, a bonding layer 253, the functional layer 204, an insulating layer 205, the functional layer 206, the bonding layer 207, the conductive layer 208, and the substrate 259.

In the light-emitting portion 804, the functional layer 206 is provided over the insulating layer 205. The substrate 251 and the insulating layer 205 are attached to each other with the bonding layer 253.

As the insulating layer 205, an insulating layer having an excellent gas barrier property, an excellent water-resistant property, an excellent moisture-resistant property, or the like is preferably used.

As an insulating layer having an excellent moisture-resistant property, a film containing nitrogen and silicon (e.g., a silicon nitride film or a silicon nitride oxide film), a film containing nitrogen and aluminum (e.g., an aluminum nitride film), or the like can be used. Alternatively, a silicon oxide film, a silicon oxynitride film, an aluminum oxide film, or the like can be used.

For example, the water vapor transmittance of the insulating layer having an excellent moisture-resistant property is lower than or equal to  $1 \times 10^{-5}$  [g/(m<sup>2</sup>·day)], preferably lower than or equal to  $1 \times 10^{-6}$  [g/(m<sup>2</sup>·day)], further preferably lower than or equal to  $1 \times 10^{-7}$  [g/(m<sup>2</sup>·day)], still further preferably lower than or equal to  $1 \times 10^{-8}$  [g/(m<sup>2</sup>·day)].

In the driver circuit portion 806, the functional layer 204 is provided over the insulating layer 205.

The conductive layer 208 is electrically connected to the FPC 808 through the connector 825.

The substrate 251 and the substrate 259 are attached to each other with the bonding layer 207. Note that as shown in FIG. 3C, the substrate 251 and the substrate 259 may be attached to each other with not only the bonding layer 207 but also the bonding layer 253. For example, an end portion of the substrate 259 may be in contact with the bonding layer 253. FIG. 3C includes a first region (R1), a second region (R2), and a third region (R3).

The bonding layer 253 may extend beyond an end portion of at least one of the substrate 251 and the substrate 259. In

that case, the bonding layer 253 can cover a side surface of at least one of the substrate 251 and the substrate 259. FIG. 3D illustrates an example in which the bonding layer 253 is in contact with end portions of the substrate 251 and the substrate 259.

The end portion of the bonding layer 253 extends beyond the end portions of the substrate 251 and the substrate 259. FIG. 3E illustrates an example in which the bonding layer 253 is in contact with an end portion of the substrate 251.

A bonding layer 254 may be used in addition to the bonding layer 207 and the bonding layer 253 to cover a side surface of at least one of the substrate 251 and the substrate 259.

#### Structure Example a-3

FIG. 4A is a top view of a light-emitting device. FIG. 4B is a cross-sectional view taken along a dashed-dotted line B1-B2 in FIG. 4A. FIG. 4C illustrates a modification example of FIG. 4B. FIG. 4D is a cross-sectional view taken along a dashed-dotted line B3-B4 in FIG. 4A.

The light-emitting device illustrated in FIG. 4A includes the light-emitting portion 804 and the driver circuit portion 806. Portions other than the light-emitting portion 804 in the light-emitting device can be regarded as non-light-emitting portions. In other words, the non-light-emitting portion is provided outside the light-emitting portion 804 to have a frame-like shape. For example, the driver circuit portion 806 is a non-light-emitting portion.

The light-emitting device in FIGS. 4A to 4D includes the substrate 251, the bonding layer 253, the functional layer 204, the insulating layer 205, the functional layer 206, the bonding layer 207, the conductive layer 208, an insulating layer 225, a functional layer 256, a bonding layer 257, and the substrate 259.

The light-emitting portion 804 includes the functional layer 206 and the functional layer 256. The functional layer 206 is closer to the substrate 251 than the bonding layer 207 is, and the functional layer 256 is closer to the substrate 259 than the bonding layer 207 is.

Examples of the functional layer 256 include a coloring layer (e.g., a color filter) and a light-blocking layer (e.g., a black matrix). The functional layer 256 may be a sensor such as a touch sensor.

The substrate 251 and the insulating layer 205 are attached to each other with the bonding layer 253. The substrate 259 and the insulating layer 225 are attached to each other with the bonding layer 257. As the insulating layer 205 and the insulating layer 225, an insulating layer having an excellent gas barrier property, an excellent water-resistant property, an excellent moisture-resistant property, or the like is preferably used.

The conductive layer 208 is electrically connected to the FPC 808 through the connector 825. Unlike in the structure examples a-1 and a-2, the substrate 251 and the substrate 259 have the same size in the structure example a-3. The conductive layer 208 and the connector 825 can be connected to each other through an opening provided in the substrate 259, the bonding layer 257, the insulating layer 225, and the bonding layer 207.

The substrate 251 and the substrate 259 are attached to each other with the bonding layer 207.

FIG. 4B illustrates an example in which on the side of the light-emitting device on which the driver circuit portion 806 is provided, the non-light-emitting portion does not have a region whose thickness is smaller than that of the light-emitting portion; however, as shown in FIG. 4C, the non-

light-emitting portion may have a region whose thickness is smaller than that of the light-emitting portion, on the side of the light-emitting device on which the driver circuit portion **806** is provided. In that case, entry of impurities such as moisture and oxygen into the light-emitting device can be further inhibited.

Example of Manufacturing Method of Structure  
Example a-2

An example of a manufacturing method of the above structure example a-2 is described with reference to FIGS. **5A** to **5E**, FIGS. **6A** and **6B**, and FIGS. **7A** and **7B**. FIGS. **5A** to **5E**, FIGS. **6A** and **6B**, and FIGS. **7A** and **7B** each illustrate a cross-sectional structure in a step, which is taken along the dashed-dotted line **A3-A4** (see FIG. **1A**).

First, a separation layer **203** is formed over the formation substrate **201**, the insulating layer **205** is formed over the separation layer **203**, and the functional layer **206** is formed over the insulating layer **205** (FIG. **5A**). Note that the insulating layer **205** and the functional layer **206** can be collectively referred to as a layer to be separated.

Although an example in which the separation layer is formed to have an island shape is described here, one embodiment of the present invention is not limited to such an example. Furthermore, the insulating layer **205** may be formed to have an island shape. In this step, materials are selected that would cause separation at the interface between the formation substrate **201** and the separation layer **203**, the interface between the separation layer **203** and the insulating layer **205**, or in the separation layer **203** when the formation substrate **201** and the insulating layer **205** are separated. In this embodiment, an example in which separation occurs at the interface between the insulating layer **205** and the separation layer **203** is described; however, one embodiment of the present invention is not limited to such an example and depends on a material used for the separation layer **203** or the insulating layer **205**.

As the formation substrate **201**, a substrate having at least heat resistance high enough to withstand process temperature in a manufacturing process is used. As the formation substrate **201**, for example, a glass substrate, a quartz substrate, a sapphire substrate, a semiconductor substrate, a ceramic substrate, a metal substrate, a resin substrate, or a plastic substrate can be used.

Note that it is preferable to use a large-sized glass substrate as the formation substrate **201** in terms of productivity. For example, a glass substrate having a size greater than or equal to the 3rd generation (550 mm×650 mm) and less than or equal to the 10th generation (2950 mm×3400 mm) or a glass substrate having a larger size than the 10th generation can be used.

In the case where a glass substrate is used as the formation substrate **201**, as a base film, an insulating film such as a silicon oxide film, a silicon oxynitride film, a silicon nitride film, or a silicon nitride oxide film is preferably formed between the formation substrate **201** and the separation layer **203**, in which case contamination from the glass substrate can be prevented.

The separation layer **203** can be formed using an element selected from tungsten, molybdenum, titanium, tantalum, niobium, nickel, cobalt, zirconium, zinc, ruthenium, rhodium, palladium, osmium, iridium, and silicon; an alloy material containing any of the elements; a compound material containing any of the elements; or the like. A crystal structure of a layer containing silicon may be amorphous, microcrystal, or polycrystal. Furthermore, a metal oxide

such as aluminum oxide, gallium oxide, zinc oxide, titanium dioxide, indium oxide, indium tin oxide, indium zinc oxide, or an In—Ga—Zn oxide can be used. The separation layer **203** is preferably formed using a high-melting point metal material such as tungsten, titanium, or molybdenum, in which case the degree of freedom of the process for forming the insulating layer **205** and the functional layer **206** can be increased.

The separation layer **203** can be formed by, for example, a sputtering method, a plasma CVD method, a coating method (including a spin coating method, a droplet discharging method, a dispensing method, and the like), a printing method, or the like. The thickness of the separation layer **203** is, for example, greater than or equal to 1 nm and less than or equal to 200 nm, or preferably greater than or equal to 10 nm and less than or equal to 100 nm.

In the case where the separation layer **203** has a single-layer structure, a tungsten layer, a molybdenum layer, or a layer containing a mixture of tungsten and molybdenum is preferably formed. Alternatively, a layer containing an oxide or an oxynitride of tungsten, a layer containing an oxide or an oxynitride of molybdenum, or a layer containing an oxide or an oxynitride of a mixture of tungsten and molybdenum may be formed. Note that the mixture of tungsten and molybdenum is an alloy of tungsten and molybdenum, for example.

In the case where the separation layer **203** is formed to have a stacked-layer structure including a layer containing tungsten and a layer containing an oxide of tungsten, the layer containing an oxide of tungsten may be formed as follows: the layer containing tungsten is formed first and an insulating film formed of an oxide is formed thereover, so that the layer containing an oxide of tungsten is formed at the interface between the tungsten layer and the insulating film. Alternatively, the layer containing an oxide of tungsten may be formed by performing thermal oxidation treatment, oxygen plasma treatment, nitrous oxide (N<sub>2</sub>O) plasma treatment, treatment with a highly oxidizing solution such as ozone water, or the like on the surface of the layer containing tungsten. Plasma treatment or heat treatment may be performed under an atmosphere of oxygen, nitrogen, or nitrous oxide alone, or a mixed gas of any of these gasses and another gas. Surface condition of the separation layer **203** is changed by the plasma treatment or heat treatment, whereby adhesion between the separation layer **203** and the insulating layer **205** can be controlled.

Note that the separation layer is not necessary in the case where separation at the interface between the formation substrate and the layer to be separated is possible. For example, a glass substrate is used as the formation substrate, and an organic resin such as polyimide, polyester, polyolefin, polyamide, polycarbonate, or acrylic is formed in contact with the glass substrate. Next, adhesion between the formation substrate and the organic resin is improved by laser light irradiation or heat treatment. Then, an insulating layer, a functional layer, and the like are formed over the organic resin. After that, separation at the interface between the formation substrate and the organic resin can be performed by performing laser light irradiation with energy density higher than that of the above laser light irradiation or performing heat treatment at a temperature higher than that of the above heat treatment. Moreover, the interface between the formation substrate and the organic resin may be soaked in a liquid to perform separation.

In the case where the above method is employed, the insulating film, the transistor, and the like are formed over the organic resin having low heat resistance, and thus it is

difficult to expose the substrate to high temperatures in the manufacturing process. Here, a manufacturing process at high temperatures is dispensable for a transistor including an oxide semiconductor; therefore, the transistor can be favorably formed over the organic resin.

Note that the organic resin may be used as the substrate of the device. Alternatively, the organic resin may be removed and another substrate may be attached to the exposed surface using an adhesive.

Alternatively, separation at the interface between a metal layer and the organic resin may be performed in the following manner: the metal layer is provided between the formation substrate and the organic resin and current is made to flow in the metal layer so that the metal layer is heated.

The insulating layer **205** preferably has a single-layer structure or a stacked-layer structure including any of a silicon nitride film, a silicon oxynitride film, a silicon oxide film, a silicon nitride oxide film, and the like.

The insulating layer **205** can be formed by a sputtering method, a plasma CVD method, a coating method, a printing method, or the like. For example, the insulating layer **205** is formed at a temperature higher than or equal to 250° C. and lower than or equal to 400° C. by a plasma CVD method, whereby the insulating layer **205** can be a dense film having an excellent moisture-resistant property. Note that the thickness of the insulating layer **205** is preferably greater than or equal to 10 nm and less than or equal to 3000 nm, or further preferably greater than or equal to 200 nm and less than or equal to 1500 nm.

In this embodiment, at least a light-emitting element (organic EL element) is formed as the functional layer **206**. A transistor, a capacitor, or the like may also be formed. Alternatively, a display element other than the light-emitting element may be formed. A coloring layer or a light-blocking layer may be formed.

Then, the bonding layer **207** and a partition **209** are formed over the formation substrate **201** or the substrate **259**.

The bonding layer **207** and the partition **209** may be formed over either the formation substrate **201** or the substrate **259**. Both the bonding layer **207** and the partition **209** may be formed over one of the substrates, or alternatively, the bonding layer **207** may be formed over one substrate and the partition **209** may be formed over the other substrate.

The bonding layer **207** is preferably formed to overlap with the separation layer **203** and the insulating layer **205**. In that case, the yield of separation of the formation substrate **201** can be increased. In the case where the bonding layer **207** is formed over the substrate **259**, it is acceptable as long as the bonding layer **207** overlaps with the separation layer **203** and the insulating layer **205** when the formation substrate **201** and the substrate **259** overlap with each other in a later step.

As shown in FIG. 5B, an end portion of the bonding layer **207** is preferably positioned on an inner side of an end portion of the separation layer **203**. Alternatively, the end portion of the bonding layer **207** and that of the separation layer **203** may overlap with each other. Accordingly, strong adhesion between the formation substrate **201** and the substrate **259** can be suppressed; thus, a decrease in yield of a subsequent separation process can be suppressed.

The partition **209** is formed to surround the bonding layer **207** and to have a frame-like shape, with a gap left between the partition **209** and the bonding layer **207**. In the case where the partition **209** is formed over the substrate other than the substrate over which the bonding layer **207** is

formed, it is acceptable as long as the partition **209** surrounds the bonding layer **207** with a gap left therebetween in a later step in which the formation substrate **201** and the substrate **259** overlap with each other.

The thickness of the bonding layer **207** and that of the partition **209** are each greater than or equal to 1 μm and less than or equal to 200 μm, preferably greater than or equal to 1 μm and less than or equal to 100 μm, further preferably greater than or equal to 1 μm and less than or equal to 50 μm, for example.

There is no particular limitation on methods for forming the bonding layer **207** and the partition **209**; for example, a droplet discharge method, a printing method (a screen printing method or an offset printing method), a coating method such as a spin coating method or a spray coating method, a dipping method, a dispenser method, or a nano-imprint method can be employed.

The partition **209** may be formed using the same material as the bonding layer **207**. The partition **209** is preferably formed using a material having higher viscosity than the bonding layer **207**. When the partition **209** is formed using a material with high viscosity, entry of impurities such as moisture from the air can be inhibited.

For the bonding layer **207** and the partition **209**, various curable adhesives such as a resin, a reactive curable adhesive, a thermosetting adhesive, an anaerobic adhesive, and a photo-curable adhesive such as an ultraviolet curable adhesive can be used. Examples of these adhesives and resin include an epoxy resin, an acrylic resin, a silicone resin, a phenol resin, a polyimide resin, an imide resin, a poly(vinyl chloride) (PVC) resin, a polyvinyl butyral (PVB) resin, and an ethylene vinyl acetate (EVA) resin. In particular, a material with low moisture permeability, such as an epoxy resin, is preferred.

Furthermore, the resin may include a drying agent. As the drying agent, for example, a substance that adsorbs moisture by chemical adsorption, such as an oxide of an alkaline earth metal (e.g., calcium oxide or barium oxide), can be used. Alternatively, a substance that adsorbs moisture by physical adsorption, such as zeolite or silica gel, may be used. The drying agent is preferably included, in which case it can suppress deterioration of the functional element due to entry of moisture in the air and can improve the reliability of the light-emitting device.

The above resin may include a leveling agent or a surface-active agent.

When a leveling agent or a surface-active agent is added to the resin, surface tension of the resin can be reduced and the wettability thereof can be increased. High wettability allows uniform application of the resin. Accordingly, inclusion of bubbles at the time of attachment of the pair of substrates can be inhibited, and the probability of a cohesive failure of the bonding layer and interfacial failure between the bonding layer and a layer to be bonded can be reduced. Display defects of the light-emitting device can also be inhibited.

As the leveling agent or the surface-active agent, a material that does not adversely affect the light-emitting element and the like is used. For example, an epoxy resin to which a fluorine-based leveling agent is added at greater than or equal to 0.01 wt % and less than or equal to 0.5 wt % may be used.

In addition, a filler with a high refractive index or a light-scattering member may be mixed into the resin, in which case the efficiency of light extraction from the light-

emitting element can be improved. For example, titanium oxide, barium oxide, zeolite, zirconium, or the like can be used.

Next, under a reduced-pressure atmosphere, the formation substrate **201** and the substrate **259** overlap with each other, so that the functional layer **206** is positioned in the space surrounded by the partition **209**, the formation substrate **201**, and the substrate **259** (FIG. 5B). As a result, the space is in a reduced-pressure state. Since there is a gap between the bonding layer **207** and the partition **209**, a hollow portion is formed therebetween.

Next, the formation substrate **201** and the substrate **259** are exposed to an air atmosphere. Accordingly, atmospheric pressure is applied to the formation substrate **201** and the substrate **259**. Then, the bonding layer **207** spreads toward an end portion of the light-emitting device and fills the hollow portion. As a result, the end portion of the light-emitting device partly has a smaller thickness than the middle portion (FIG. 5C). Note that the bonding layer **207** is preferably formed using a material having lower viscosity than the partition **209** because the bonding layer **207** spreads sufficiently in the above step.

Note that to prevent the distance between the substrates from being too small, the functional layer **206** preferably includes a spacer (e.g., a spacer **823** described in Embodiment 2 (FIG. 26B)).

Then, the bonding layer **207** and the partition **209** are cured. The bonding layer **207** and the partition **209** are cured under an air atmosphere or a pressurized atmosphere.

Curing the partition **209** allows the reduced-pressure state in the light-emitting device to be easily maintained; thus, it is preferable to cure the partition **209** before the bonding layer **207** is cured. Alternatively, the partition **209** and the bonding layer **207** may be cured in the same step.

For example, in the case where a photocurable resin is used for the partition **209** and a thermosetting resin is used for the bonding layer **207**, it is preferable that the partition **209** be cured first by light irradiation and then, the bonding layer **207** be cured by heating. In the case where a thermosetting resin is used for both the partition **209** and the bonding layer **207**, the partition **209** and the bonding layer **207** are cured at the same time by heating.

Shorter curing time for the partition **209** and the bonding layer **207** reduces the time required for manufacture of the light-emitting device. In the case where the bonding layer **207** is formed using a thermosetting resin, for example, high heating temperature leads to short curing time but also causes many bubbles to be formed in the resin, and the yield of the light-emitting device is reduced in some cases. In view of the above, heating is performed under pressure in one embodiment of the present invention, which can inhibit formation of bubbles even when the heating temperature is high. The resin can be cured using, for example, a pressure defoaming device (e.g., autoclave).

For example, in the case of a resin that takes approximately 12 hours to be cured when heated at 40° C., bubbles are formed therein if heating is performed at 80° C. for 1 hour without pressure application; however, when heating is performed at 80° C. for 1 hour under a pressure of 0.5 MPa, the resin can be cured in a short time while such formation of bubbles is inhibited. By performing heating and pressure application at the same time, bubbles formed at the time of attachment can be dissolved in the resin. Furthermore, bubbles formed before the heating and pressure application can be removed. Note that even when the resin is preserved at room temperature under atmospheric pressure after the heating, bubbles are not formed.

The step of curing a bonding layer by heating with pressure application can be applied to a step other than the step of curing the bonding layer **207**.

Then, a separation starting point (or separation trigger) is preferably formed. The separation starting point is formed in a region where the bonding layer **207** and the separation layer **203** overlap with each other.

The separation starting point can be formed through laser light irradiation, etching of the separation layer using a gas, a solution, or the like, division of the substrate, or mechanical removal such as making a cut with a sharp cutting tool such as a knife, a scalpel, or a cutter, for example. Formation of a separation starting point facilitates separation of the separation layer and the layer to be separated.

For example, when the substrate **259** can be divided with a cutting tool or the like, a separation starting point can be formed by making a cut in the substrate **259**, the bonding layer **207**, and the insulating layer **205**.

In the case where laser light irradiation is employed, a region where the bonding layer **207** in a cured state, the insulating layer **205**, and the separation layer **203** overlap with one another is preferably irradiated with the laser light. Although laser light irradiation may be performed from either substrate side, it is preferably performed from the formation substrate **201** side in which the separation layer **203** is provided, in order to prevent the functional element or the like from being irradiated with scattered light. Note that a material that transmits the laser light is used for the substrate on the side where laser light irradiation is performed.

The insulating layer **205** is cracked (or broken), whereby the separation starting point can be formed. At this time, not only the insulating layer **205** but also part of the separation layer **203** and the bonding layer **207** may be removed. Laser light irradiation enables part of the films included in the insulating layer **205**, the separation layer **203**, or the bonding layer **207** to be dissolved, evaporated, or thermally broken.

It is preferable that at a separation process, force of separating the insulating layer **205** and the separation layer **203** be concentrated at the separation starting point; therefore, it is preferable to form the separation starting point not at the center portion of the bonding layer **207** in a cured state but in the vicinity of the end portion. It is particularly preferable to form the separation starting point in the vicinity of the corner portion compared to the vicinity of the side portion among the vicinities of the end portion. In such a case where the separation starting point is formed in a position not overlapping with the bonding layer **207**, it is preferable that the position at which the separation starting point is formed be in a short distance from the bonding layer **207**, whereby the separation layer **203** and the insulating layer **205** can be separated surely; specifically, it is preferable that the separation starting point be formed in a distance from the end portion of the bonding layer **207** within 1 mm.

There is no particular limitation on a laser used to form a separation starting point. For example, a continuous wave laser or a pulsed oscillation laser can be used. Note that a condition for laser light irradiation such as frequency, power density, energy density, or beam profile is controlled as appropriate in consideration of thicknesses, materials, or the like of the formation substrate **201** and the separation layer **203**.

Laser light irradiation is preferably employed, in which case the substrate does not need to be, for example, cut to form the separation starting point and generation of dust can be suppressed. In addition, the time taken to form the separation starting point can be shortened. Moreover, the

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formation substrate **201** can be reused easily because dust that remains on the surface of the formation substrate **201** can be reduced. Furthermore, laser light irradiation results in low cost and can be easily applied to mass production because it does not cause wear of a sharp cutting tool such as a cutter. Separation can be started by pulling the end portion of any of the substrates and therefore can be easily applied to mass production.

Then, the insulating layer **205** and the formation substrate **201** are separated from each other from the formed separation starting point. At this time, one of the substrates is preferably fixed to a suction stage or the like. For example, the formation substrate **201** may be fixed to the suction stage to separate the insulating layer **205** from the formation substrate **201**. Alternatively, the substrate **259** may be fixed to a suction stage to separate the formation substrate **201** from the substrate **259**.

For example, the insulating layer **205** and the formation substrate **201** may be separated from the separation starting point by mechanical force (e.g., a separation process with a human hand or a gripper, or a separation process by rotation of a roller).

Alternatively, the formation substrate **201** and the insulating layer **205** may be separated by filling the interface between the separation layer **203** and the insulating layer **205** with a liquid such as water. A portion between the separation layer **203** and the insulating layer **205** absorbs a liquid through capillarity action, so that separation occurs easily. Furthermore, an adverse effect on the functional element included in the insulating layer **205** due to static electricity caused at separation (e.g., a phenomenon in which a semiconductor element is damaged by static electricity) can be suppressed. Note that liquid can be sprayed in the form of mist or steam. As the liquid, pure water, an organic solvent, a neutral, alkaline, or acid aqueous solution, an aqueous solution in which a salt is dissolved, or the like can be used.

Note that after the separation, the bonding layer **207**, the partition **209**, or the like which does not contribute to attachment between the insulating layer **205** and the substrate **259** and which remains over the substrate **259** may be removed. By such removal, an adverse effect on the functional element in a subsequent step (e.g., entry of impurities) can be preferably suppressed. For example, an unnecessary resin can be removed by wiping or cleaning.

Next, to the insulating layer **205** that is exposed by separation of the formation substrate **201**, the substrate **251** is attached with the use of the bonding layer **253** (FIG. 5D). An end portion of the substrate **259** may be cut such that end portions of the substrate **259** and the substrate **251** are substantially aligned with each other (FIG. 5E). Furthermore, an end portion of the light-emitting device may be cut such that end portions of the substrate **251**, the bonding layer **253**, the insulating layer **205**, the bonding layer **207**, and the substrate **259** are substantially aligned with each other (see FIG. 3B).

The bonding layer **253** can be formed using a material that can be used for the bonding layer **207** or the partition **209**.

Although FIG. 5C illustrates an example in which both the formation substrate **201** and the substrate **259** are curved, only one substrate is curved in some cases depending on a method for fixing the formation substrate **201** or the substrate **259**, the kinds of the materials used for the formation substrate **201** and the substrate **259**, or the thickness of the formation substrate **201** or the substrate **259**. FIG. 6A illustrates an example in which only the substrate **259** is curved and FIG. 7A illustrates an example in which only the

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formation substrate **201** is curved. In either case, the end portion of the light-emitting device partly has a smaller thickness than the middle portion. Note that the hollow portion may be left or filled with the bonding layer **207**. FIG. 6B and FIG. 7B illustrate the light-emitting devices in FIG. 6A and FIG. 7A from which the formation substrate **201** is separated and to which the substrate **251** is attached. Note that the formation substrate **201** and the substrate **259** can have a thickness of, for example, greater than or equal to 10  $\mu\text{m}$  and less than or equal to 10 mm.

Through the above process, the light-emitting device described in the structure example a-2 can be manufactured.

#### Example of Manufacturing Method of Structure Example a-3

An example of a manufacturing method of the above structure example a-3 is described with reference to FIGS. 8A to 8D, FIGS. 9A to 9D, and FIGS. 10A and 10B. FIGS. 8A to 8D, FIGS. 9A to 9D, and FIGS. 10A and 10B each illustrate a cross-sectional structure in a step, which is taken along the dashed-dotted line B3-B4 (see FIG. 4A).

First, the separation layer **203** is formed over the formation substrate **201**, the insulating layer **205** is formed over the separation layer **203**, and the functional layer **206** is formed over the insulating layer **205** (FIG. 8A). Furthermore, a separation layer **223** is formed over a formation substrate **221**, the insulating layer **225** is formed over the separation layer **223**, and the functional layer **256** is formed over the insulating layer **225** (FIG. 8B).

Although the separation layer **203** and the separation layer **223** have the same size in this embodiment (FIG. 8C), the two separation layers may have different sizes.

The formation substrate **221** can be formed using a material for the formation substrate **201**. The separation layer **223** can be formed using a material for the separation layer **203**. The insulating layer **225** can be formed using a material for the insulating layer **205**.

In this embodiment, at least a coloring layer is formed as the functional layer **256**. A light-blocking layer, a light-emitting element, a display element, a transistor, a touch sensor, a capacitor, or the like may also be formed.

Then, the bonding layer **207** and the partition **209** are formed over the formation substrate **201** or the formation substrate **221**. The bonding layer **207** and the partition **209** may be formed over either the formation substrate **201** or the formation substrate **221**. Both the bonding layer **207** and the partition **209** may be formed over one of the substrates, or alternatively, the bonding layer **207** may be formed over one substrate and the partition **209** may be formed over the other substrate.

The bonding layer **207** is preferably formed in such a manner that it overlaps with the separation layer **203**, the insulating layer **205**, the insulating layer **225**, and the separation layer **223** in a later step in which the formation substrate **201** and the formation substrate **221** overlap with each other. In that case, the yield of separation of the formation substrate **201** and the formation substrate **221** can be increased.

As shown in FIG. 8C, an end portion of the bonding layer **207** is preferably positioned on an inner side of at least an end portion of either the separation layer **203** or the separation layer **223** (the separation layer which is desirably separated first). Accordingly, strong adhesion between the formation substrate **201** and the formation substrate **221** can be suppressed; thus, a decrease in yield of a subsequent separation process can be suppressed.

The partition 209 is formed to surround the bonding layer 207 and to have a frame-like shape, with a gap left between the partition 209 and the bonding layer 207. In the case where the partition 209 is formed over the substrate other than the substrate over which the bonding layer 207 is formed, it is acceptable as long as the partition 209 surrounds the bonding layer 207 with a gap left therebetween in a later step in which the formation substrate 201 and the formation substrate 221 overlap with each other.

Next, under a reduced-pressure atmosphere, the formation substrate 201 and the formation substrate 221 overlap with each other, so that the functional layer 206 and the functional layer 256 are positioned in the space surrounded by the partition 209, the formation substrate 201, and the formation substrate 221 (FIG. 8C). As a result, the space is in a reduced-pressure state. Since there is a gap between the bonding layer 207 and the partition 209, a hollow portion is formed therebetween.

Next, the formation substrate 201 and the formation substrate 221 are exposed to an air atmosphere. Accordingly, atmospheric pressure is applied to the formation substrate 201 and the formation substrate 221. Then, the bonding layer 207 spreads toward an end portion of the light-emitting device and fills the hollow portion. As a result, the end portion of the light-emitting device partly has a smaller thickness than the middle portion (FIG. 8D).

Then, the bonding layer 207 and the partition 209 are cured. The bonding layer 207 and the partition 209 are cured under an air atmosphere or a pressurized atmosphere.

Curing the partition 209 allows the reduced-pressure state in the light-emitting device to be easily maintained; thus, it is preferable to cure the partition 209 before the bonding layer 207 is cured. Alternatively, the partition 209 and the bonding layer 207 may be cured in the same step.

For example, in the case where a photocurable resin is used for the partition 209 and a thermosetting resin is used for the bonding layer 207, it is preferable that the partition 209 be cured first by light irradiation and then, the bonding layer 207 be cured by heating. In the case where a thermosetting resin is used for both the partition 209 and the bonding layer 207, the partition 209 and the bonding layer 207 are cured at the same time by heating.

After that, a separation starting point is formed.

Either the formation substrate 201 or the formation substrate 221 may be separated first. In the case where the separation layers differ in size, a substrate over which a larger separation layer is formed may be separated first or a substrate over which a smaller separation layer is formed may be separated first. In the case where an element such as a semiconductor element, a light-emitting element, or a display element is formed only over one of the substrates, the substrate on the side where the element is formed may be separated first or the other substrate may be separated first. Here, an example in which the formation substrate 201 is separated first is described. In this case, the separation starting point is formed in a region where the bonding layer 207 and the separation layer 203 overlap with each other.

Then, the insulating layer 205 and the formation substrate 201 are separated from each other from the formed separation starting point (FIG. 9A).

Note that the bonding layer 207 and the partition 209 that extend beyond the separation starting point remain on at least one of the formation substrate 201 and the formation substrate 221. Although FIG. 9A illustrates an example in which the partition 209 remains on both substrates, one embodiment of the present invention is not limited to this example.

Next, to the insulating layer 205 that is exposed by separation of the formation substrate 201, the substrate 251 is attached with the use of the bonding layer 253 (FIG. 9B).

Next, a separation starting point is formed in a region where the bonding layer 207 and the separation layer 223 overlap with each other. Then, the insulating layer 225 and the formation substrate 221 are separated from each other from the formed separation starting point. Next, to the insulating layer 225 that is exposed by separation of the formation substrate 221, the substrate 259 is attached with the use of the bonding layer 257 (FIG. 9C).

The substrate 251 and the substrate 259 may be attached to each other with not only the bonding layer 207 but also the bonding layer 253. For example, an end portion of the substrate 251 may be in contact with the bonding layer 257 as illustrated in FIG. 9D.

Although FIG. 8D illustrates an example in which both the formation substrate 201 and the formation substrate 221 are curved, only one substrate is curved in some cases depending on a method for fixing the formation substrate 201 or the formation substrate 221, the kinds of the materials used for the formation substrate 201 and the formation substrate 221, or the thickness of the formation substrate 201 or the formation substrate 221. FIG. 10A illustrates an example in which only the formation substrate 221 is curved. In this case, the end portion of the light-emitting device partly has a smaller thickness than the middle portion. FIG. 10B illustrates the light-emitting device in FIG. 10A from which the formation substrate 201 and the formation substrate 221 are separated, in which the substrate 251 and the insulating layer 205 are attached to each other, and in which the substrate 259 and the insulating layer 225 are attached to each other. The light-emitting device in which only the formation substrate 201 is curved is also one embodiment of the present invention.

In the above-described example of a manufacturing method of the structure example a-3, the procedure can be adopted in which the pair of formation substrates each provided with the layer to be separated are attached to each other, separation is performed, and then the substrates of the light-emitting device are attached. Therefore, the formation substrates having low flexibility can be attached to each other when the layers to be separated are attached to each other, whereby alignment accuracy at the time of attachment can be improved as compared to the case where flexible substrates are attached to each other.

Through the above process, the light-emitting device described in the structure example a-3 can be manufactured.

#### Structure Example b-1

FIG. 11B is a cross-sectional view taken along a dashed-dotted line A1-A2 in FIG. 11A. FIG. 11C is a cross-sectional view taken along a dashed-dotted line A3-A4 in FIG. 11A.

The light-emitting device illustrated in FIG. 11A includes the light-emitting portion 804 and the driver circuit portion 806. Portions other than the light-emitting portion 804 in the light-emitting device can be regarded as non-light-emitting portions. In other words, the non-light-emitting portion is provided outside the light-emitting portion 804 to have a frame-like shape. For example, the driver circuit portion 806 is a non-light-emitting portion.

The light-emitting device in FIGS. 11A to 11C includes the substrate 251, the functional layer 204, the functional layer 206, the bonding layer 207, the conductive layer 208, and the substrate 259.

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In the light-emitting portion **804**, the functional layer **206** is provided over the substrate **251**.

The functional layer **206** includes a light-emitting element and may also include a transistor, a capacitor, or the like.

In the driver circuit portion **806**, the functional layer **204** is provided over the substrate **251**.

The functional layer **204** includes a transistor and may also include a capacitor, a resistor, a switch element, or the like.

The conductive layer **208** is electrically connected to an external input terminal through which a signal or a potential from the outside is transmitted to the driver circuit portion **806**. In FIG. **11B**, the conductive layer **208** is electrically connected to the FPC **808** through the connector **825**.

The substrate **251** and the substrate **259** are attached to each other with the bonding layer **207**.

As shown in FIGS. **11B** and **11C**, the thickness of the light-emitting device is uniform (or substantially uniform) in the light-emitting portion **804**. Meanwhile, the non-light-emitting portion has a region whose thickness is smaller than that of the light-emitting portion **804**. In other words, a gap between the substrate **251** and the substrate **259** in part of the non-light-emitting portion is smaller than that in the light-emitting portion **804**. Part of the non-light-emitting portion of the light-emitting device has a smaller thickness than the light-emitting portion **804** as described above, whereby entry of impurities such as moisture and oxygen into the light-emitting device can be inhibited.

Formation of a thin region in the non-light-emitting portion can be verified by observation of interference fringes generated in the non-light-emitting portion, for example. In the non-light-emitting portion, a region including interference fringes may be formed to have a width of greater than or equal to 0.1 mm, greater than or equal to 0.5 mm, or greater than or equal to 1 mm, and less than or equal to 10 mm, less than or equal to 5 mm, or less than or equal to 2 mm. When interference fringes are generated in the light-emitting portion **804**, display quality deteriorates in some cases. It is thus preferable that in the light-emitting portion **804**, interference fringes not be formed and the thickness of the light-emitting device be uniform (or substantially uniform).

FIGS. **11B** and **11C** illustrate an example in which a thin region is formed on four sides of the light-emitting device (an example in which a thin region is formed to have a frame-like shape in the non-light-emitting portion). FIGS. **11B** and **11C** illustrate an example in which the substrate **259**, which is not provided with the functional layer **206**, has a depression (a recessed, depressed portion). One embodiment of the present invention is not limited to the structure illustrated in FIGS. **11B** and **11C**.

On at least one side of the light-emitting device, the non-light-emitting portion has a region whose thickness is smaller than that of the light-emitting portion. One or both of the pair of substrates has a depression.

FIGS. **12A** to **12D** are examples of a cross-sectional view taken along the dashed-dotted line **A1-A2** in FIG. **11A**.

FIG. **12A** illustrates an example in which the non-light-emitting portion in a portion where the driver circuit portion **806** and the conductive layer **208** are provided does not have a region whose thickness is smaller than that of the light-emitting portion. The shortest distance from the side of the light-emitting portion **804** that is adjacent to the driver circuit portion **806** to an end portion of the light-emitting device is longer than the shortest distance from the other sides of the light-emitting portion **804** to other end portions of the light-emitting device; therefore, on the side of the

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light-emitting device on which the driver circuit portion **806** is provided, impurities are unlikely to reach the light-emitting element or the like. In that case, the non-light-emitting portion does not necessarily have a portion whose thickness is smaller than that of the light-emitting portion. In the above manner, the element included in the driver circuit portion **806** can be prevented from deteriorating because of bending. Moreover, the conductive layer **208** and the FPC **808** can be electrically connected to each other reliably. The elements included in the driver circuit portion **806** can be prevented from being subjected to pressure at the time of formation of the depression, and thus damage to the elements can be inhibited.

Note that as illustrated in FIG. **11B**, a depression may be formed in the driver circuit portion **806**. For example, the substrate may have a depression in a portion that overlaps with a scan line driver circuit or a signal line driver circuit. The substrate may have a depression in a portion that overlaps with a contact portion between an electrode (an anode or a cathode) of the light-emitting element and a wiring. A thin region may also be formed in a portion of the light-emitting portion as long as providing the thin region in the portion does not adversely affect display quality; for example, a thin region may be formed to overlap with a dummy pixel or an end portion of a color filter.

FIG. **12B** illustrates an example in which the substrate **251** provided with the functional layer **206** has a depression. As illustrated in FIG. **12C**, the pair of substrates (the substrate **251** and substrate **259**) may each have a depression. In the case where the non-light-emitting portion has a region thinner than the light-emitting portion in a portion not overlapping with the dashed-dotted line **A1-A2** in FIG. **11A**, the thickness of the light-emitting portion and that of the non-light-emitting portion may be the same (or substantially the same) in a portion overlapping with the dashed-dotted line **A1-A2** in FIG. **11A**, as illustrated in FIG. **12D**.

FIGS. **13A** to **13D** are examples of a cross-sectional view taken along the dashed-dotted line **A3-A4** in FIG. **11A**.

FIG. **13A** illustrates an example in which the substrate **251** provided with the functional layer **206** has a depression. As illustrated in FIG. **13B**, the pair of substrates (the substrate **251** and substrate **259**) may each have a depression. Here, the position of the depression may be different between the substrate **251** and substrate **259**. In that case, the non-light-emitting portion has a plurality of regions thinner than the light-emitting portion. As in the non-light-emitting portion on the right side in FIG. **13C**, the depression of the substrate **251** and that of the substrate **259** may be formed in the same position. In that case, part of the non-light-emitting portion has a thickness much smaller than that of the light-emitting portion.

The smaller the minimum thickness of the light-emitting device is, the more difficult it is for impurities to reach the functional element and the more a reduction in the reliability of the light-emitting device can be inhibited, which is preferable. As in the non-light-emitting portion on the left side in FIG. **13C**, the depression of the substrate **251** and that of the substrate **259** may be formed in different positions. In the case where the non-light-emitting portion has a region thinner than the light-emitting portion in a portion not overlapping with the dashed-dotted line **A3-A4** in FIG. **11A**, the thickness of the light-emitting portion and that of the non-light-emitting portion may be the same (or substantially the same) in a portion overlapping with the dashed-dotted line **A3-A4** in FIG. **11A**, as illustrated in FIG. **13D**.

The cross-sectional views in FIGS. **12A** to **12D** taken along the dashed-dotted line **A1-A2** and those in FIGS. **13A**

to 13D taken along the dashed-dotted line A3-A4 can be combined as appropriate. For example, as in a combination of FIG. 12C and FIG. 13C, which are the cross-sectional view taken along the dashed-dotted line A1-A2 in FIG. 11A and that taken along the dashed-dotted line A3-A4, the non-light-emitting portion may have a region whose thickness is smaller than that of the light-emitting portion, on three of the four sides of the light-emitting device. Alternatively, as in a combination of FIG. 12B and FIG. 13A, the non-light-emitting portion may have a region whose thickness is smaller than that of the light-emitting portion, on two of the four sides of the light-emitting device. Further alternatively, as in a combination of FIG. 12A and FIG. 13D, the non-light-emitting portion may have a region whose thickness is smaller than that of the light-emitting portion, on one of the four sides of the light-emitting device.

Although the functional layer 206 is formed directly over the substrate 251 in the structure example b-1, one embodiment of the present invention is not limited to this structure. As described in the following structure examples b-2 and b-3, the functional layer 206 that has been formed over a formation substrate may be transferred to the substrate 251.

#### Structure Example b-2

FIG. 14A is a cross-sectional view taken along the dashed-dotted line A1-A2 in FIG. 11A. FIG. 14B is a cross-sectional view taken along the dashed-dotted line A3-A4 in FIG. 11A.

The light-emitting device in FIGS. 14A and 14B includes the substrate 251, the bonding layer 253, the functional layer 204, the insulating layer 205, the functional layer 206, the bonding layer 207, the conductive layer 208, and the substrate 259.

In the light-emitting portion 804, the functional layer 206 is provided over the insulating layer 205. The substrate 251 and the insulating layer 205 are attached to each other with the bonding layer 253.

As the insulating layer 205, an insulating layer having an excellent gas barrier property, an excellent water-resistant property, an excellent moisture-resistant property, or the like is preferably used.

In the driver circuit portion 806, the functional layer 204 is provided over the insulating layer 205.

The conductive layer 208 is electrically connected to the FPC 808 through the connector 825.

The substrate 251 and the substrate 259 are attached to each other with the bonding layer 207.

FIGS. 15A to 15D are examples of a cross-sectional view taken along the dashed-dotted line A3-A4 in FIG. 11A.

The number of depressions formed in a substrate on any one side of the light-emitting device is not limited and may be one or more. For example, FIGS. 15A and 15B show examples in which a plurality of depressions are formed in a substrate on each of two sides of the light-emitting device. As illustrated in FIG. 15A, the depression does not necessarily have a round shape but may have an angular shape. In one embodiment of the present invention, the substrate does not necessarily have a depression. For example, as illustrated in FIG. 15C, the light-emitting device may have the thinnest region at the end portion; in other words, the substrate may have a projection (a protruding portion). As illustrated in FIG. 15D, the pair of substrates (the substrate 251 and substrate 259) may each have a depression.

#### Structure Example b-3

FIG. 16A is a cross-sectional view taken along the dashed-dotted line A1-A2 in FIG. 11A. FIG. 16B is a cross-sectional view taken along the dashed-dotted line A3-A4 in FIG. 11A.

The light-emitting device in FIGS. 16A and 16B includes the substrate 251, the bonding layer 253, the functional layer 204, the insulating layer 205, the functional layer 206, the bonding layer 207, the conductive layer 208, the insulating layer 225, the functional layer 256, the bonding layer 257, and the substrate 259.

It is preferable that a region thinner than the light-emitting portion not overlap with the driver circuit portion 806 in the non-light-emitting portion on the side of the light-emitting device on which the driver circuit portion 806 is provided, as illustrated in FIG. 16A. For example, a region thinner than the light-emitting portion is preferably provided on an outer side of the driver circuit portion 806.

In the example illustrated in FIG. 16B, the thickness of the light-emitting portion 804 and that of an end portion of the light-emitting device are the same (or substantially the same); however, one embodiment of the present invention is not limited to the example. The end portion of the light-emitting device may be thicker than the light-emitting portion 804 as illustrated in FIG. 16C. That is, the light-emitting device may have the thickest region at an end portion. The end portion of the light-emitting device may be thinner than the light-emitting portion 804 as illustrated in FIG. 16D. At this time, a portion thinner than the end portion of the light-emitting device may be provided in the non-light-emitting portion of the light-emitting device, or the end portion of the light-emitting device may be the thinnest region in the light-emitting device.

FIG. 17A is a top view of a light-emitting device. FIG. 17B is a cross-sectional view taken along a dashed-dotted line B1-B2 in FIG. 17A. FIG. 17C is a cross-sectional view taken along a dashed-dotted line B3-B4 in FIG. 17A.

The light-emitting device illustrated in FIG. 17A includes the light-emitting portion 804 and the driver circuit portion 806. Portions other than the light-emitting portion 804 in the light-emitting device can be regarded as non-light-emitting portions. In other words, the non-light-emitting portion is provided outside the light-emitting portion 804 to have a frame-like shape. For example, the driver circuit portion 806 is a non-light-emitting portion.

The light-emitting device in FIGS. 17A to 17C includes the substrate 251, the bonding layer 253, the functional layer 204, the insulating layer 205, the functional layer 206, the bonding layer 207, the conductive layer 208, the insulating layer 225, the functional layer 256, the bonding layer 257, and the substrate 259.

The light-emitting portion 804 includes the functional layer 206 and the functional layer 256. The functional layer 206 is closer to the substrate 251 than the bonding layer 207 is, and the functional layer 256 is closer to the substrate 259 than the bonding layer 207 is.

Examples of the functional layer 256 include a coloring layer and a light-blocking layer. The functional layer 256 may be a sensor such as a touch sensor.

The substrate 251 and the insulating layer 205 are attached to each other with the bonding layer 253. The substrate 259 and the insulating layer 225 are attached to each other with the bonding layer 257. As the insulating layer 205 and the insulating layer 225, an insulating layer having an excellent gas barrier property, an excellent water-



resistant property, an excellent moisture-resistant property, or the like is preferably used.

The conductive layer **208** is electrically connected to the FPC **808** through the connector **825**. Unlike in the structure illustrated in FIG. **16A**, the substrate **251** and the substrate **259** have the same size in the example illustrated in FIGS. **17A** and **17B**. The conductive layer **208** and the connector **825** can be connected to each other through an opening provided in the substrate **259**, the bonding layer **257**, the insulating layer **225**, and the bonding layer **207**.

The substrate **251** and the substrate **259** are attached to each other with the bonding layer **207**.

In the example illustrated in FIGS. **17A** and **17B**, the substrate **259** has a depression; however, the substrate **251**, which is a supporting substrate for the conductive layer **208** connected to the FPC **808**, may have a depression as illustrated in FIGS. **18A** and **18B**. As illustrated in FIGS. **18C** and **18D**, the pair of substrates (the substrate **251** and substrate **259**) may each have a depression.

FIG. **17B** and FIG. **18A** each illustrate an example in which on the side of the light-emitting device on which the driver circuit portion **806** is provided, the non-light-emitting portion does not have a region whose thickness is smaller than that of the light-emitting portion; however, as shown in FIG. **18C**, the non-light-emitting portion may have a region whose thickness is smaller than that of the light-emitting portion, on the side of the light-emitting device on which the driver circuit portion **806** is provided. In that case, entry of impurities such as moisture and oxygen into the light-emitting device can be further inhibited.

#### Example of Manufacturing Method of Structure Example b-1

An example of a manufacturing method of the above structure example b-1 is described with reference to FIGS. **19A** to **19D**. First, the functional layer **206** is formed over the substrate **251**. Then, the bonding layer **207** is formed over the substrate **251** or the substrate **259**. Next, under a reduced-pressure atmosphere, the substrate **251** and the substrate **259** overlap with each other, so that the functional layer **206** is surrounded by the bonding layer **207**, the substrate **251**, and the substrate **259**. A light-emitting device **10** at this stage is placed in an apparatus capable of pressure application as illustrated in FIG. **19A**. For example, a press, a hot press, or the like can be used.

FIG. **19A** illustrates an example of using a hot press that includes an upper plate **2000a** and a lower plate **2000b**. The hot press has a heat source and heats one or both of the upper plate **2000a** and the lower plate **2000b**. A substrate **2100b** is provided over the lower plate **2000b** with a cushioning material **2005b** positioned therebetween. The light-emitting device **10** is placed over the substrate **2100b**. Over the light-emitting device **10**, a substrate **2101** having a projection **2102** is provided. The projection **2102** is in contact with the substrate **259**. The projection **2102** overlaps with a non-light-emitting portion of the light-emitting device **10**. Between the substrate **2101** and the upper plate **2000a**, a cushioning material **2005a** and a substrate **2100a** are provided.

The projection **2102** can be formed over the substrate **2101** with the use of an organic material such as a resin or an inorganic material such as a metal. There is no limitation on a method for forming the projection **2102**, and a sputtering method, a CVD method, a coating method, a printing method, a droplet discharge method, or a dispensing method may be used, for example. Alternatively, a mold having a

projection may be used. The mold can be formed using the material that can be used for the substrate. For example, the mold can be formed using a resin, glass, a metal, or an alloy.

The projection **2102** can be formed by curing an adhesive provided over the substrate **2101**.

As illustrated in FIGS. **19B** and **19C**, the projection **2102** may be formed to have a frame-like shape. It is possible to employ a structure in which the projection **2102** is not positioned at end portions of the substrate **2101** as illustrated in FIG. **19B** or a structure in which the projection **2102** is positioned at end portions of the substrate **2101** as illustrated in FIG. **19C**. The projection **2102** may be formed on three of the four sides of the substrate **2101** as illustrated in FIG. **19D**, or may be provided on two sides or one side thereof. Note that the projection **2102** is not necessarily formed parallel to a side of the substrate **2101**.

When pressure is applied to the light-emitting device **10** in the state shown in FIG. **19A** with the hot press, a thin region can be formed in the non-light-emitting portion of the light-emitting device **10**.

Note that the bonding layer **207** is preferably cured while pressure is applied to the light-emitting device **10** because the light-emitting device **10** can easily retain the shape formed by the pressure application.

In the case where the bonding layer **207** is formed using a thermosetting adhesive or a UV delay curing adhesive, for example, the light-emitting device **10** is preferably subjected to heat and pressure with the use of the hot press.

The time or load for the pressure application is not particularly limited. The load can be, for example, greater than or equal to 0.5 t, greater than or equal to 0.8 t, or greater than or equal to 1.0 t and less than or equal to 1.5 t, less than or equal to 2.0 t, or less than or equal to 3.0 t. The heating time is not particularly limited and can be determined in accordance with cure conditions of the material for the bonding layer **207**, or the like. The heating temperature can be determined in accordance with the heat resistance of the materials used for the light-emitting device **10**. For example, the heating temperature can be higher than or equal to 80° C., higher than or equal to 90° C., or higher than or equal to 100° C. and lower than or equal to 120° C., lower than or equal to 150° C., or lower than or equal to 200° C.

In addition, heating or light irradiation may be additionally performed after the pressure application to cure the bonding layer **207**.

Through the above process, the light-emitting device described in the structure example b-1 can be manufactured.

#### Example of Manufacturing Method of Structure Example b-2

An example of a manufacturing method of the above structure example b-2 is described with reference to FIG. **19A** and FIGS. **20A** to **20D**. FIGS. **20A** to **20D** each illustrate a cross-sectional structure in a step, which is taken along the dashed-dotted line A3-A4 (see FIG. **11A**).

First, the separation layer **203** is formed over the formation substrate **201**, the insulating layer **205** is formed over the separation layer **203**, and the functional layer **206** is formed over the insulating layer **205** (FIG. **20A**). Note that the insulating layer **205** and the functional layer **206** can be collectively referred to as a layer to be separated.

In this embodiment, at least a light-emitting element (organic EL element) is formed as the functional layer **206**. A transistor, a capacitor, a touch sensor, or the like may also be formed. Alternatively, a display element other than the

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light-emitting element may be formed. A coloring layer or a light-blocking layer may be formed.

Then, the bonding layer 207 is formed over the formation substrate 201 or the substrate 259.

The bonding layer 207 is preferably formed to overlap with the separation layer 203 and the insulating layer 205. In that case, the yield of separation of the formation substrate 201 can be increased. In the case where the bonding layer 207 is formed over the substrate 259, it is acceptable as long as the bonding layer 207 overlaps with the separation layer 203 and the insulating layer 205 when the formation substrate 201 and the substrate 259 overlap with each other in a later step.

As shown in FIG. 20B, an end portion of the bonding layer 207 is preferably positioned on an inner side of an end portion of the separation layer 203. Alternatively, the end portion of the bonding layer 207 and that of the separation layer 203 may overlap with each other. Accordingly, strong adhesion between the formation substrate 201 and the substrate 259 can be suppressed; thus, a decrease in yield of a subsequent separation process can be suppressed. In the case where the bonding layer 207 is formed using a material with high fluidity, a partition is preferably used to hold the bonding layer 207.

The thickness of the bonding layer 207 is greater than or equal to 1  $\mu\text{m}$  and less than or equal to 200  $\mu\text{m}$ , preferably greater than or equal to 1  $\mu\text{m}$  and less than or equal to 100  $\mu\text{m}$ , further preferably greater than or equal to 1  $\mu\text{m}$  and less than or equal to 50  $\mu\text{m}$ , for example.

Next, under a reduced-pressure atmosphere, the formation substrate 201 and the substrate 259 overlap with each other, so that the functional layer 206 is surrounded by the bonding layer 207, the formation substrate 201, and the substrate 259 (FIG. 20B). Then, the light-emitting device 10 shown in FIG. 20B is placed in the above-described press (see FIG. 19A). With the projection 2102 formed on the substrate 2101, pressure is applied to the non-light-emitting portion of the light-emitting device 10.

At this time, a width W2 of the depression formed in the substrate 259 of the light-emitting device 10 is larger than a width W1 of the projection 2102 (FIG. 20C). For example, the width W2 is larger than 1 time and smaller than or equal to 1.5 times, smaller than or equal to 2 times, or smaller than or equal to 3 times the width W1. The width W2 may be more than 3 times the width W1. The depth of the depression formed in the substrate 259 of the light-emitting device 10 is smaller than or equal to a height d of the projection 2102. The width W2 can be larger than or equal to 1 time, larger than or equal to 5 times, or larger than or equal to 10 times and smaller than or equal to 20 times, smaller than or equal to 50 times, or smaller than or equal to 100 times the depth of the depression.

For example, the depth of the depression can be greater than or equal to 0.01 mm, greater than or equal to 0.05 mm, or greater than or equal to 0.1 mm and less than or equal to 2 mm, less than or equal to 1 mm, or less than or equal to 0.5 mm. The width W2 can be greater than or equal to 0.1 mm, greater than or equal to 1 mm, or greater than or equal to 1 cm and less than or equal to 10 cm, less than or equal to 5 cm, or less than or equal to 3 cm. The width W2 is preferably larger than or equal to 0 times and smaller than or equal to 1 time the width of the non-light-emitting portion, and may be larger than or equal to 0.2 times and smaller than or equal to 0.8 times, or larger than or equal to 0.4 times and smaller than or equal to 0.6 times the width of the non-light-emitting portion. Note that the width W2 is not

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necessarily the width of the depression and may be the width of the region thinner than the light-emitting portion.

When pressure is applied to the light-emitting device 10 with the press, a thin portion can be formed in the non-light-emitting portion of the light-emitting device 10 (FIG. 20D). Heating is preferably performed at the same time as the pressure application to cure the bonding layer 207.

Next, the formation substrate 201 and the insulating layer 205 are separated from each other. Here, a separation starting point for separation of the formation substrate 201 is preferably formed. The separation starting point is formed in a region where the bonding layer 207 and the separation layer 203 overlap with each other.

The insulating layer 205 is cracked (or broken), whereby the separation starting point can be formed.

Then, the insulating layer 205 and the formation substrate 201 are separated from each other from the formed separation starting point.

Next, to the insulating layer 205 that is exposed by separation of the formation substrate 201, the substrate 251 is attached with the use of the bonding layer 253. A step of, for example, cutting an end portion (e.g., part of the substrate 259 that is not in contact with the bonding layer 207) of the light-emitting device is performed, so that the light-emitting device illustrated in FIG. 14B can be manufactured.

Through the above process, the light-emitting device described in the structure example b-2 can be manufactured.

#### Example 1 of Manufacturing Method of Structure Example b-3

An example of a manufacturing method of the above structure example b-3 is described with reference to FIG. 19A and FIGS. 21A to 21D. FIGS. 21A to 21D each illustrate a cross-sectional structure in a step, which is taken along the dashed-dotted line B3-B4 (see FIG. 17A).

First, the separation layer 203 is formed over the formation substrate 201, the insulating layer 205 is formed over the separation layer 203, and the functional layer 206 is formed over the insulating layer 205 (FIG. 21A). Furthermore, the separation layer 223 is formed over the formation substrate 221, the insulating layer 225 is formed over the separation layer 223, and the functional layer 256 is formed over the insulating layer 225 (FIG. 21B).

Although the separation layer 203 and the separation layer 223 have the same size in this embodiment (FIG. 21C), the two separation layers may have different sizes.

The formation substrate 221 can be formed using a material for the formation substrate 201. The separation layer 223 can be formed using a material for the separation layer 203. The insulating layer 225 can be formed using a material for the insulating layer 205.

In this embodiment, at least a coloring layer is formed as the functional layer 256. A light-blocking layer, a light-emitting element, a display element, a transistor, a touch sensor, a capacitor, or the like may also be formed.

Then, the bonding layer 207, a partition 242, and a temporary sealing layer 244 are formed over the formation substrate 201 or the formation substrate 221.

The bonding layer 207, the partition 242, and the temporary sealing layer 244 may be formed over either the formation substrate 201 or the formation substrate 221. All of the bonding layer 207, the partition 242, and the temporary sealing layer 244 may be formed over one of the substrates, or alternatively, the bonding layer 207 and the

partition 242 may be formed over one substrate and the temporary sealing layer 244 may be formed over the other substrate.

The bonding layer 207 is preferably formed in such a manner that it overlaps with the separation layer 203, the insulating layer 205, the insulating layer 225, and the separation layer 223 in a later step in which the formation substrate 201 and the formation substrate 221 overlap with each other. In that case, the yield of separation of the formation substrate 201 and the formation substrate 221 can be increased.

As shown in FIG. 21C, an end portion of the bonding layer 207 is preferably positioned on an inner side of at least an end portion of either the separation layer 203 or the separation layer 223 (the separation layer which is desirably separated first). Accordingly, strong adhesion between the formation substrate 201 and the formation substrate 221 can be suppressed; thus, a decrease in yield of a subsequent separation process can be suppressed.

The thickness of the partition 242 and that of the temporary sealing layer 244 are each greater than or equal to 1  $\mu\text{m}$  and less than or equal to 200  $\mu\text{m}$ , preferably greater than or equal to 1  $\mu\text{m}$  and less than or equal to 100  $\mu\text{m}$ , further preferably greater than or equal to 1  $\mu\text{m}$  and less than or equal to 50  $\mu\text{m}$ , for example.

There is no particular limitation on methods for forming the partition 242 and the temporary sealing layer 244; for example, a droplet discharge method, a printing method (a screen printing method or an offset printing method), a coating method such as a spin coating method or a spray coating method, a dipping method, a dispenser method, a nanoimprint method, or the like can be employed.

The partition 242 may be formed using the same material as the bonding layer 207. The partition 242 is preferably formed using a material having higher viscosity than the bonding layer 207. When the partition 242 is formed using a material with high viscosity, entry of impurities such as moisture from the air can be inhibited.

A variety of materials that can be used for the bonding layer 207 can be used for the partition 242 and the temporary sealing layer 244.

Next, under a reduced-pressure atmosphere, the formation substrate 201 and the formation substrate 221 overlap with each other, so that the functional layer 206 and the functional layer 256 are surrounded by the temporary sealing layer 244, the formation substrate 201, and the formation substrate 221 (FIG. 21C).

Then, at least part of the temporary sealing layer 244 may be cured. When the light-emitting device 10 is exposed to an air atmosphere, atmospheric pressure is applied to the formation substrate 201 and the formation substrate 221. As a result, the reduced-pressure state of the space surrounded by the temporary sealing layer 244, the formation substrate 201, and the formation substrate 221 is maintained. Thus, impurities such as moisture in the air can be prevented from entering the light-emitting device 10.

Then, the light-emitting device 10 shown in FIG. 21C is placed in the above-described press (see FIG. 19A). With the projection 2102 formed on the substrate 2101, pressure is applied to the non-light-emitting portion of the light-emitting device 10.

When pressure is applied to the light-emitting device 10 with the press, a thin portion can be formed in the non-light-emitting portion of the light-emitting device 10 (FIG. 21D). Heating is preferably performed at the same time as the pressure application to cure the bonding layer 207. In

addition, heating or light irradiation may be additionally performed after the pressure application to cure the bonding layer 207.

After that, a separation starting point is formed. Then, the insulating layer and the formation substrate are separated from each other from the formed separation starting point. To the insulating layer that is exposed by separation of the formation substrate, a substrate is attached with the use of a bonding layer.

Either the formation substrate 201 or the formation substrate 221 may be separated first. In the case where the separation layers differ in size, a substrate over which a larger separation layer is formed may be separated first or a substrate over which a smaller separation layer is formed may be separated first. In the case where an element such as a semiconductor element, a light-emitting element, or a display element is formed only over one of the substrates, the substrate on the side where the element is formed may be separated first or the other substrate may be separated first.

Through the above process, the light-emitting device described in the structure example b-3 can be manufactured.

Note that in one embodiment of the present invention, a method for forming a thin region in the non-light-emitting portion is not limited to the method in which pressure is applied to the non-light-emitting portion to change the shape of the light-emitting device.

#### Example 2 of Manufacturing Method of Structure Example b-3

An example of a manufacturing method of the above structure example b-3 is described with reference to FIGS. 22A to 22D. FIGS. 22A to 22D each illustrate a cross-sectional structure in a step, which is taken along the dashed-dotted line B3-B4 (see FIG. 17A).

First, the separation layer 203 is formed over the formation substrate 201, the insulating layer 205 is formed over the separation layer 203, and the functional layer 206 is formed over the insulating layer 205 (FIG. 22A). Furthermore, a projection 246 is formed over the formation substrate 221, the separation layer 223 is formed over the projection 246, the insulating layer 225 is formed over the separation layer 223, and the functional layer 256 is formed over the insulating layer 225 (FIG. 22B).

Then, the bonding layer 207 is formed over the formation substrate 201 or the formation substrate 221.

Next, under a reduced-pressure atmosphere, the formation substrate 201 and the formation substrate 221 overlap with each other, so that the functional layer 206 and the functional layer 256 are surrounded by the bonding layer 207, the formation substrate 201, and the formation substrate 221 (FIG. 22C). Then, the bonding layer 207 is cured. Then, the insulating layer and the formation substrate are separated from each other. To the insulating layer that is exposed by separation of the formation substrate, a substrate is attached with the use of a bonding layer.

FIG. 22D illustrates an example in which the formation substrate 221 is separated ahead of the formation substrate 201.

In the case where a projection is formed on the formation substrate in advance or a formation substrate having a projection is used, pressure application to the light-emitting device during manufacture is not needed. Accordingly, the manufacturing process of the light-emitting device can be simplified and a reduction in yield can be inhibited.

In the above-described examples 1 and 2 of a manufacturing method of the structure example b-3, the procedure can be adopted in which the pair of formation substrates each provided with the layer to be separated are attached to each other, separation is performed, and then the substrates of the light-emitting device are attached. Therefore, the formation substrates having low flexibility can be attached to each other when the layers to be separated are attached to each other, whereby alignment accuracy at the time of attachment can be improved as compared to the case where flexible substrates are attached to each other.

#### Example of Plan View of Light-Emitting Device

The light-emitting device of one embodiment of the present invention may be a system-on-panel in which part or the whole of a driver circuit including a transistor is formed over the same substrate as a light-emitting portion in an integrated manner.

In FIGS. 23A1 and 23A2, a light-emitting portion 4002 is sealed with a first substrate 4001, a bonding layer (not shown), and a second substrate 4006. In FIGS. 23A1 and 23A2, over a region of the first substrate 4001 that does not overlap with the second substrate 4006, a signal line driver circuit 4003 and a scan line driver circuit 4004 formed over the respective separate substrates are mounted. Signals and potentials are supplied from an FPC 4018a and an FPC 4018b to the signal line driver circuit 4003, the scan line driver circuit 4004, or the light-emitting portion 4002.

In FIGS. 23B1, 23B2, and 23C, the light-emitting portion 4002 and the scan line driver circuit 4004 are sealed with the first substrate 4001, a bonding layer (not shown), and the second substrate 4006. In FIGS. 23B1, 23B2, and 23C, over a region of the first substrate 4001 that does not overlap with the second substrate 4006, the signal line driver circuit 4003 formed over a separate substrate is mounted. In FIGS. 23B1, 23B2, and 23C, signals and potentials are supplied from an FPC 4018 to the signal line driver circuit 4003, the scan line driver circuit 4004, or the light-emitting portion 4002.

Although FIGS. 23B1, 23B2, and 23C each illustrate an example in which the signal line driver circuit 4003 is formed separately and mounted on the first substrate 4001, the present invention is not limited to this structure. The scan line driver circuit may be separately formed and then mounted, or only part of the signal line driver circuit or part of the scan line driver circuit may be separately formed and then mounted.

The connection method of a separately formed driver circuit is not particularly limited; wire bonding, a COG, a TCP, a chip on film (COF), or the like can be used. FIGS. 23A1 and 23A2 each illustrate an example in which the signal line driver circuit 4003 and the scan line driver circuit 4004 are mounted by a COG of a COF; FIGS. 23B1 and 23B2 each illustrate an example in which the signal line driver circuit 4003 is mounted by a COG of a COF; and FIG. 23C illustrates an example in which the signal line driver circuit 4003 is mounted by a TCP.

A frame-like non-light-emitting portion is provided outside the light-emitting portion 4002. Here, the non-light-emitting portion means a portion other than the light-emitting portion 4002 in a region overlapping with the second substrate 4006 over the first substrate 4001. A region 4005 in the non-light-emitting portion is a region thinner than the light-emitting portion 4002. For example, in the region 4005, at least one of the first substrate 4001 and the second substrate 4006 have a depression.

Although FIG. 23A1 illustrates an example in which the region 4005 having a frame-like shape exists in part of the non-light-emitting portion, the region 4005 may be provided in the entire non-light-emitting portion as illustrated in FIG. 23A2. The region 4005 does not necessarily have a frame-like shape. In the example illustrated in FIG. 23B1, the region 4005 extends through three sides of the light-emitting device. In the example illustrated in FIG. 23B2, the region 4005 is provided on each of three sides of the light-emitting device. In this manner, the plurality of regions 4005 may be provided. In the example illustrated in FIG. 23C, the scan line driver circuit 4004 overlaps with the region 4005. In the case where part or the whole of a driver circuit that includes a transistor is provided on the same substrate as the light-emitting portion in the light-emitting device, the driver circuit and the region 4005 may partly overlap with each other.

As described in this embodiment, in one embodiment of the present invention, entry of impurities through a side surface of the light-emitting device can be inhibited because the non-light-emitting portion has a region thinner than the light-emitting portion. Thus, the light-emitting device can be highly reliable.

This embodiment can be combined with any other embodiment as appropriate.

#### Embodiment 2

In this embodiment, a light-emitting device of one embodiment of the present invention will be described with reference to drawings.

Although a light-emitting device including an organic EL element is mainly described in this embodiment as an example, one embodiment of the present invention is not limited to this example. The light-emitting devices described in this embodiment each have a region thinner than a light-emitting portion in a non-light-emitting portion and are thus highly reliable.

#### Specific Example 1

FIG. 24A is a plan view of a light-emitting device, and FIG. 24B and FIG. 31A show examples of a cross-sectional view taken along a dashed-dotted line D1-D2 in FIG. 24A. Specifically, FIG. 24B and FIG. 31A show an application example of the structure example a-3 and an application example of the structure example b-3, respectively. The light-emitting device in Specific Example 1 is a top-emission light-emitting device using a color filter method. In this embodiment, the light-emitting device can have a structure in which subpixels of three colors of red (R), green (G), and blue (B), for example, express one color; a structure in which subpixels of four colors of R, G, B, and white (W) express one color; a structure in which subpixels of four colors of R, G, B, and yellow (Y) express one color; or the like. There is no particular limitation on color elements, and colors other than R, G, B, W, and Y may be used. For example, cyan or magenta, or the like may be used.

The light-emitting device illustrated in FIG. 24A includes the light-emitting portion 804, the driver circuit portion 806, and the FPC 808.

The light-emitting devices in FIG. 24B and FIG. 31A each include a first flexible substrate 701, a first bonding layer 703, a first insulating layer 705, a first functional layer (a plurality of transistors, a conductive layer 857, an insulating layer 815, an insulating layer 817, a plurality of light-emitting elements, and an insulating layer 821), a third

bonding layer 822, a second functional layer (a coloring layer 845 and a light-blocking layer 847), a second insulating layer 715, a second bonding layer 713, and a second flexible substrate 711. The third bonding layer 822, the second insulating layer 715, the second bonding layer 713, and the second flexible substrate 711 transmit visible light. Light-emitting elements and transistors included in the light-emitting portion 804 and the driver circuit portion 806 are sealed with the first flexible substrate 701, the second flexible substrate 711, and the third bonding layer 822.

The light-emitting portion 804 includes the transistor 820 and a light-emitting element 830 over the first flexible substrate 701 with the first bonding layer 703 and the first insulating layer 705 provided therebetween. The light-emitting element 830 includes a lower electrode 831 over the insulating layer 817, an EL layer 833 over the lower electrode 831, and an upper electrode 835 over the EL layer 833. The lower electrode 831 is electrically connected to a source electrode or a drain electrode of the transistor 820. An end portion of the lower electrode 831 is covered with the insulating layer 821. The lower electrode 831 preferably reflects visible light. The upper electrode 835 transmits visible light.

The light-emitting portion 804 includes the coloring layer 845 overlapping with the light-emitting element 830 and the light-blocking layer 847 overlapping with the insulating layer 821. The space between the light-emitting element 830 and the coloring layer 845 is filled with the third bonding layer 822.

The insulating layer 815 has an effect of inhibiting diffusion of impurities to a semiconductor included in the transistor. As the insulating layer 817, an insulating layer having a planarization function is preferably selected in order to reduce surface unevenness due to the transistor.

The driver circuit portion 806 includes a plurality of transistors over the first flexible substrate 701 with the first bonding layer 703 and the first insulating layer 705 provided therebetween. In FIG. 24B and FIG. 31A, one of the transistors included in the driver circuit portion 806 is illustrated.

The first insulating layer 705 and the first flexible substrate 701 are attached to each other with the first bonding layer 703. The second insulating layer 715 and the second flexible substrate 711 are attached to each other with the second bonding layer 713. The first insulating layer 705 and the second insulating layer 715 are preferably highly resistant to moisture, in which case impurities such as water can be prevented from entering the light-emitting element 830 or the transistor 820, leading to higher reliability of the light-emitting device.

The conductive layer 857 is electrically connected to an external input terminal through which a signal or a potential from the outside is transmitted to the driver circuit portion 806. Here, an example in which the FPC 808 is provided as the external input terminal is described. To prevent an increase in the number of manufacturing steps, the conductive layer 857 is preferably formed using the same material and the same step(s) as those of the electrode or the wiring in the light-emitting portion or the driver circuit portion. Here, an example is described in which the conductive layer 857 is formed using the same material and the same step(s) as those of the electrodes of the transistor 820.

In the light-emitting devices in FIG. 24B and FIG. 31A, the FPC 808 is positioned over the second flexible substrate 711. The connector 825 is connected to the conductive layer 857 through an opening provided in the second flexible substrate 711, the second bonding layer 713, the second

insulating layer 715, the third bonding layer 822, the insulating layer 817, and the insulating layer 815. The connector 825 is also connected to the FPC 808. The FPC 808 and the conductive layer 857 are electrically connected to each other via the connector 825. When the conductive layer 857 and the second flexible substrate 711 overlap with each other, an opening is formed in the second flexible substrate 711 (or a substrate with an opening portion is used) so that the conductive layer 857, the connector 825, and the FPC 808 can be electrically connected to each other.

A modification example of the light-emitting device shown in FIGS. 24A and 24B is described. FIG. 25A is a plan view of a light-emitting device, and FIG. 25B and FIG. 31B show examples of a cross-sectional view taken along a dashed-dotted line D3-D4 in FIG. 25A. Specifically, FIG. 25B and FIG. 31B show an application example of the structure example a-3 and an application example of the structure example b-3, respectively.

The light-emitting devices shown in FIGS. 25A and 25B and FIG. 31B are examples in which the first flexible substrate 701 and the second flexible substrate 711 have different sizes. The FPC 808 is located over the second insulating layer 715 and does not overlap with the second flexible substrate 711. The connector 825 is connected to the conductive layer 857 through an opening provided in the second insulating layer 715, the third bonding layer 822, the insulating layer 817, and the insulating layer 815. Since no opening needs to be provided in the second flexible substrate 711, there is no limitation on the material for the second flexible substrate 711.

FIG. 26A and FIG. 32 illustrate examples of a cross-sectional view taken along a dashed-dotted line D5-D6 in FIG. 24A and FIG. 25A.

Each of the light-emitting device in FIG. 24B and FIG. 26A and the light-emitting device in FIG. 25B and FIG. 26A has, on three of the four sides thereof, a portion where the thickness continuously (smoothly) decreases from the light-emitting portion side of the non-light-emitting portion to an end portion of the light-emitting device. With the above structure, entry of impurities through a side surface of the light-emitting device can be inhibited.

In the non-light-emitting portion of the light-emitting device illustrated in FIG. 31A and FIG. 32 and that of the light-emitting device illustrated in FIG. 31B and FIG. 32, the second flexible substrate 711, the second bonding layer 713, and the second insulating layer 715 have depressions. In the non-light-emitting portion of the light-emitting device illustrated in FIG. 31B and FIG. 32, the first flexible substrate 701, the first bonding layer 703, and the first insulating layer 705 have depressions. The non-light-emitting portion has a portion thinner than the light-emitting portion in this manner, whereby entry of impurities through a side surface of the light-emitting device can be inhibited.

In the case where an organic resin with a low gas barrier property or a low moisture-resistant property is used for forming an insulating layer, it is preferable that the insulating layer not be exposed at an end portion of the light-emitting device. With this structure, entry of impurities through a side surface of the light-emitting device can be inhibited. For example, a structure may be employed in which the insulating layer 817 is not provided at an end portion of the light-emitting device as illustrated in FIGS. 27A and 27B, FIG. 28, FIG. 31B, and FIG. 32.

FIG. 26B illustrates a modification example of the light-emitting portion 804.

The light-emitting device illustrated in FIG. 26B includes insulating layers 817a and 817b and a conductive layer 856

over the insulating layer **817a**. The source electrode or the drain electrode of the transistor **820** and the lower electrode of the light-emitting element **830** are electrically connected to each other through the conductive layer **856**.

The light-emitting device in FIG. **26B** includes the spacer **823** over the insulating layer **821**. The spacer **823** can adjust the gap between the first flexible substrate **701** and the second flexible substrate **711**.

The light-emitting device in FIG. **26B** includes an overcoat **849** covering the coloring layer **845** and the light-blocking layer **847**. The space between the light-emitting element **830** and the overcoat **849** is filled with the bonding layer **822**.

FIG. **26C** illustrates a modification example of the light-emitting element **830**.

Note that as illustrated in FIG. **26C**, the light-emitting element **830** may include an optical adjustment layer **832** between the lower electrode **831** and the EL layer **833**. It is preferable to use a conductive material having a light-transmitting property for the optical adjustment layer **832**. Owing to the combination of a color filter (the coloring layer) and a microcavity structure (the optical adjustment layer), light with high color purity can be extracted from the light-emitting device of one embodiment of the present invention. The thickness of the optical adjustment layer may be set in accordance with the emission color of the sub-pixel.

#### Specific Example 2

A light-emitting device illustrated in FIG. **26D** includes the first flexible substrate **701**, the first bonding layer **703**, the first insulating layer **705**, a first functional layer (a conductive layer **814**, a conductive layer **857a**, a conductive layer **857b**, the light-emitting element **830**, and the insulating layer **821**), the second bonding layer **713**, and the second flexible substrate **711**.

The conductive layer **857a** and the conductive layer **857b**, which are external connection electrodes of the light-emitting device, can each be electrically connected to an FPC or the like.

The light-emitting element **830** includes the lower electrode **831**, the EL layer **833**, and the upper electrode **835**. The end portion of the lower electrode **831** is covered with the insulating layer **821**. The light-emitting element **830** has a bottom emission structure, a top emission structure, or a dual emission structure. The electrode, the substrate, the insulating layer, and the like through each of which light is extracted transmit visible light. The conductive layer **814** is electrically connected to the lower electrode **831**.

The substrate through which light is extracted may have, as a light extraction structure, a hemispherical lens, a micro lens array, a film provided with an uneven surface structure, a light diffusing film, or the like. For example, a substrate having the light extraction structure can be formed by bonding the above lens or film to a resin substrate with an adhesive or the like having substantially the same refractive index as the substrate or the lens or film.

The conductive layer **814** is preferably, though not necessarily, provided because voltage drop due to the resistance of the lower electrode **831** can be inhibited. In addition, for a similar purpose, a conductive layer electrically connected to the upper electrode **835** may be provided over the insulating layer **821**, the EL layer **833**, the upper electrode **835**, or the like.

The conductive layer **814** can be formed to have a single-layer structure or a stacked-layer structure using a material selected from copper, titanium, tantalum, tungsten,

molybdenum, chromium, neodymium, scandium, nickel, and aluminum, an alloy material containing any of these materials as its main component, and the like. The thickness of the conductive layer **814** can be greater than or equal to 0.1  $\mu\text{m}$  and less than or equal to 3  $\mu\text{m}$ , preferably greater than or equal to 0.1  $\mu\text{m}$  and less than or equal to 0.5  $\mu\text{m}$ , for example.

#### Specific Example 3

FIG. **25A** is a plan view of a light-emitting device, and FIG. **29A** is an example of a cross-sectional view taken along the dashed-dotted line D3-D4 in FIG. **25A**. The light-emitting device in Specific Example 3 is a bottom-emission light-emitting device using a color filter method.

The light-emitting device in FIG. **29A** includes the first flexible substrate **701**, the first bonding layer **703**, the first insulating layer **705**, a first functional layer (a plurality of transistors, the conductive layer **857**, the insulating layer **815**, the coloring layer **845**, the insulating layer **817a**, the insulating layer **817b**, the conductive layer **856**, a plurality of light-emitting elements, and the insulating layer **821**), the second bonding layer **713**, and the second flexible substrate **711**. The first flexible substrate **701**, the first bonding layer **703**, the first insulating layer **705**, the insulating layer **815**, the insulating layer **817a**, and the insulating layer **817b** transmit visible light.

In Specific Example 3, the first flexible substrate **701** is curved but the second flexible substrate **711** is not. The light-emitting device in Specific Example 3 has a portion where the thickness thereof continuously (smoothly) decreases from the light-emitting portion side of the non-light-emitting portion toward an end portion of the light-emitting device. In addition, at the end portion of the light-emitting device and the vicinity thereof, a portion is provided where the thickness of the light-emitting device is smaller than that of the light-emitting portion and is uniform. With the above structure, entry of impurities through a side surface of the light-emitting device can be inhibited.

The light-emitting portion **804** includes the transistor **820**, a transistor **824**, and the light-emitting element **830** over the first flexible substrate **701** with the first bonding layer **703** and the first insulating layer **705** provided therebetween. The light-emitting element **830** includes the lower electrode **831** over the insulating layer **817b**, the EL layer **833** over the lower electrode **831**, and the upper electrode **835** over the EL layer **833**. The lower electrode **831** is electrically connected to the source electrode or the drain electrode of the transistor **820**. An end portion of the lower electrode **831** is covered with the insulating layer **821**. The upper electrode **835** preferably reflects visible light. The lower electrode **831** transmits visible light. The coloring layer **845** that overlaps with the light-emitting element **830** can be provided anywhere; for example, the coloring layer **845** may be provided between the insulating layers **817a** and **817b** or between the insulating layers **815** and **817a**.

The driver circuit portion **806** includes a plurality of transistors over the first flexible substrate **701** with the first bonding layer **703** and the first insulating layer **705** provided therebetween. In FIG. **29A**, two of the transistors included in the driver circuit portion **806** are illustrated.

The first insulating layer **705** and the first flexible substrate **701** are attached to each other with the first bonding layer **703**. The first insulating layer **705** is preferably highly resistant to moisture, in which case impurities such as water can be prevented from entering the light-emitting element

**830**, the transistor **820**, the transistor **824**, leading to higher reliability of the light-emitting device.

The conductive layer **857** is electrically connected to an external input terminal through which a signal or a potential from the outside is transmitted to the driver circuit portion **806**. Here, an example in which the FPC **808** is provided as the external input terminal is described. Furthermore, an example is described in which the conductive layer **857** is formed using the same material and the same step(s) as those of the conductive layer **856**.

A structure in which the insulating layer **817a** and the insulating layer **817b** are not provided at the end portion of the light-emitting device as illustrated in FIG. **30A** may be employed.

#### Specific Example 4

FIG. **25A** is a plan view of a light-emitting device, and FIG. **29B** is an example of a cross-sectional view taken along the dashed-dotted line D3-D4 in FIG. **25A**. The light-emitting device in Specific Example 4 is a top-emission light-emitting device using a separate coloring method.

The light-emitting device in FIG. **29B** includes the first flexible substrate **701**, the first bonding layer **703**, the first insulating layer **705**, a first functional layer (a plurality of transistors, the conductive layer **857**, the insulating layer **815**, the insulating layer **817**, a plurality of light-emitting elements, the insulating layer **821**, and the spacer **823**), the second bonding layer **713**, and the second flexible substrate **711**. The second bonding layer **713** and the second flexible substrate **711** transmit visible light.

In Specific Example 4, the second flexible substrate **711** is curved but the first flexible substrate **701** is not. The light-emitting device in Specific Example 4 has a portion where the thickness thereof continuously (smoothly) decreases from the light-emitting portion side of the non-light-emitting portion toward an end portion of the light-emitting device. With the above structure, entry of impurities through a side surface of the light-emitting device can be inhibited.

In the light-emitting device in FIG. **29B**, the connector **825** is positioned over the insulating layer **815**. The connector **825** is connected to the conductive layer **857** through an opening provided in the insulating layer **815**. Moreover, the connector **825** is connected to the FPC **808**. The FPC **808** and the conductive layer **857** are electrically connected to each other with the connector **825** provided therebetween.

A structure in which the insulating layer **817** is not provided at the end portion of the light-emitting device as illustrated in FIG. **30B** may be employed.

#### Examples of Materials

Next, materials and the like that can be used for a light-emitting device are described. Note that description of the components already described in this specification is omitted in some cases.

There is no particular limitation on the structure of the transistor in the light-emitting device. For example, a forward staggered transistor or an inverted staggered transistor may be used. Furthermore, a top-gate transistor or a bottom-gate transistor may be used. A semiconductor material used for the transistors is not particularly limited, and for example, silicon, germanium, or an organic semiconductor can be used. Alternatively, an oxide semiconductor containing at least one of indium, gallium, and zinc, such as an In—Ga—Zn-based metal oxide, may be used.

There is no particular limitation on the crystallinity of a semiconductor material used for the transistors, and an amorphous semiconductor or a semiconductor having crystallinity (a microcrystalline semiconductor, a polycrystalline semiconductor, a single crystal semiconductor, or a semiconductor partly including crystal regions) may be used. It is preferable that a semiconductor having crystallinity be used, in which case deterioration of the transistor characteristics can be inhibited.

For stable characteristics of the transistor, a base film is preferably provided. The base film can be formed to have a single-layer structure or a stacked-layer structure using an inorganic insulating film such as a silicon oxide film, a silicon nitride film, a silicon oxynitride film, or a silicon nitride oxide film. The base film can be formed by a sputtering method, a chemical vapor deposition (CVD) method (e.g., a plasma CVD method, a thermal CVD method, or a metal organic CVD (MOCVD) method), an atomic layer deposition (ALD) method, a coating method, a printing method, or the like. Note that the base film is not necessarily provided if not necessary. In each of the above specific examples, the first insulating layer **705** can serve as a base film of the transistor.

When a voltage higher than the threshold voltage of the light-emitting element is applied between the lower electrode **831** and the upper electrode **835**, holes are injected to the EL layer **833** from the anode side and electrons are injected to the EL layer **833** from the cathode side. The injected electrons and holes recombine in the EL layer **833** and a light-emitting substance contained in the EL layer **833** emits light. A conductive film that transmits visible light is used as the electrode through which light is extracted. A conductive film that reflects visible light is preferably used as the electrode through which light is not extracted.

The EL layer **833** includes at least a light-emitting layer. In addition to the light-emitting layer, the EL layer **833** may further include one or more layers containing any of a substance with a high hole-injection property, a substance with a high hole-transport property, a hole-blocking material, a substance with a high electron-transport property, a substance with a high electron-injection property, a substance with a bipolar property (a substance with a high electron- and hole-transport property), and the like.

For the EL layer **833**, either a low molecular compound or a high molecular compound can be used, and an inorganic compound may also be used. Each of the layers included in the EL layer **833** can be formed by any of the following methods: an evaporation method (including a vacuum evaporation method), a transfer method, a printing method, an inkjet method, a coating method, and the like.

The light-emitting element **830** may contain two or more kinds of light-emitting substances. Thus, for example, a light-emitting element that emits white light can be obtained. For example, a white emission can be obtained by selecting light-emitting substances so that two or more kinds of light-emitting substances emit light of complementary colors. A light-emitting substance that emits red (R) light, green (G) light, blue (B) light, yellow (Y) light, or orange (O) light or a light-emitting substance that emits light containing spectral components of two or more of R light, G light, and B light can be used, for example. A light-emitting substance that emits blue light and a light-emitting substance that emits yellow light may be used, for example. At this time, the emission spectrum of the light-emitting substance that emits yellow light preferably contains spectral components of G light and R light. The emission spectrum of the light-emitting element **830** preferably has two or more peaks

in the visible region (e.g., greater than or equal to 350 nm and less than or equal to 750 nm or greater than or equal to 400 nm and less than or equal to 800 nm).

The EL layer **833** may include a plurality of light-emitting layers. In the EL layer **833**, the plurality of light-emitting layers may be stacked in contact with one another or may be stacked with a separation layer provided therebetween. The separation layer may be provided between a fluorescent layer and a phosphorescent layer, for example.

The separation layer can be provided, for example, to prevent energy transfer by the Dexter mechanism (particularly triplet energy transfer) from a phosphorescent material in an excited state which is generated in the phosphorescent layer to a fluorescent material in the fluorescent layer. The thickness of the separation layer may be several nanometers. Specifically, the thickness of the separation layer may be greater than or equal to 0.1 nm and less than or equal to 20 nm, greater than or equal to 1 nm and less than or equal to 10 nm, or greater than or equal to 1 nm and less than or equal to 5 nm. The separation layer contains a single material (preferably, a bipolar substance) or a plurality of materials (preferably, a hole-transport material and an electron-transport material).

The separation layer may be formed using a material contained in a light-emitting layer in contact with the separation layer. This facilitates the manufacture of the light-emitting element and reduces the drive voltage. For example, in the case where the phosphorescent layer includes a host material, an assist material, and a phosphorescent material (guest material), the separation layer may be formed using the host material and the assist material. In other words, the separation layer includes a region not containing the phosphorescent material and the phosphorescent layer includes a region containing the phosphorescent material in the above structure. Accordingly, the separation layer and the phosphorescent layer can be deposited by evaporation separately depending on whether a phosphorescent material is used or not. With such a structure, the separation layer and the phosphorescent layer can be formed in the same chamber. Thus, the manufacturing costs can be reduced.

Moreover, the light-emitting element **830** may be a single element including one EL layer or a tandem element in which EL layers are stacked with a charge generation layer provided therebetween.

The light-emitting element is preferably provided between a pair of insulating layers having an excellent moisture-resistant property. In that case, entry of an impurity such as water into the light-emitting element can be inhibited, leading to inhibition of a decrease in the reliability of the light-emitting device. Specifically, the use of an insulating film having high resistance to moisture for the insulating layer **205** and the insulating layer **225** allows the light-emitting element to be located between a pair of insulating films having high resistance to moisture, by which a decrease in reliability of the light-emitting device can be prevented.

As the insulating layer **815**, for example, an inorganic insulating film such as a silicon oxide film, a silicon oxynitride film, or an aluminum oxide film can be used. As the insulating layer **817**, the insulating layer **817a**, and the insulating layer **817b**, an organic material such as a polyimide, an acrylic resin, a polyamide, a poly(imide amide), or a benzocyclobutene-based resin can be used, for example. Alternatively, a low-dielectric constant material (a low-k

material) or the like can be used. Furthermore, each insulating layer may be formed by stacking a plurality of insulating films.

The insulating layer **821** is formed using an organic insulating material or an inorganic insulating material. As the resin, for example, a polyimide resin, a polyamide resin, an acrylic resin, a siloxane resin, an epoxy resin, or a phenol resin can be used. It is particularly preferable that the insulating layer **821** be formed using a photosensitive resin material to have an opening portion over the lower electrode **831** so that a side wall of the opening portion is formed as an inclined surface with a continuous curvature.

There is no particular limitation on the method for forming the insulating layer **821**; a photolithography method, a sputtering method, an evaporation method, a droplet discharging method (e.g., an inkjet method), a printing method (e.g., a screen printing method or an off-set printing method), or the like may be used.

The spacer **823** can be formed using an inorganic insulating material, an organic insulating material, a metal material, or the like. As the inorganic insulating material and the organic insulating material, for example, a variety of materials that can be used for the aforementioned insulating layers can be used. As the metal material, titanium, aluminum, or the like can be used. When the spacer **823** containing a conductive material is electrically connected to the upper electrode **835**, a potential drop due to the resistance of the upper electrode **835** can be inhibited. The spacer **823** may have either a tapered shape or an inverse tapered shape.

For example, a conductive layer functioning as an electrode or a wiring of the transistor, an auxiliary electrode of the light-emitting element, or the like, which is used for the light-emitting device, can be formed to have a single-layer structure or a stacked-layer structure using any of metal materials such as molybdenum, titanium, chromium, tantalum, tungsten, aluminum, copper, neodymium, and scandium, and an alloy material containing any of these elements. Alternatively, the conductive layer may be formed using a conductive metal oxide. As the conductive metal oxide, indium oxide (e.g.,  $\text{In}_2\text{O}_3$ ), tin oxide (e.g.,  $\text{SnO}_2$ ), ZnO, ITO, indium zinc oxide (e.g.,  $\text{In}_2\text{O}_3\text{—ZnO}$ ), or any of these metal oxide materials in which silicon oxide is contained can be used.

The coloring layer is a colored layer that transmits light in a specific wavelength range. For example, a color filter for transmitting light in a red, green, blue, or yellow wavelength range can be used. Each coloring layer is formed in a desired position with any of various materials by a printing method, an inkjet method, an etching method using a photolithography method, or the like. In a white sub-pixel, a transparent resin may be provided so as to overlap with the light-emitting element.

The light-blocking layer is provided between the adjacent coloring layers. The light-blocking layer blocks light emitted from an adjacent light-emitting element to inhibit color mixture between adjacent light-emitting elements. Here, the coloring layer is provided such that its end portion overlaps with the light-blocking layer, whereby light leakage can be reduced. As the light-blocking layer, a material that can block light from the light-emitting element can be used; for example, a black matrix is formed using a resin material containing a metal material, pigment, or dye. Note that it is preferable to provide the light-blocking layer in a region other than the light-emitting portion, such as a driver circuit portion, in which case undesired leakage of guided light or the like can be inhibited.



Furthermore, an overcoat covering the coloring layer and the light-blocking layer may be provided. The overcoat can prevent an impurity and the like contained in the coloring layer from being diffused into the light-emitting element. The overcoat is formed with a material that transmits light emitted from the light-emitting element; for example, an inorganic insulating film such as a silicon nitride film or a silicon oxide film, an organic insulating film such as an acrylic film or a polyimide film can be used, and further, a stacked-layer structure of an organic insulating film and an inorganic insulating film may be employed.

In the case where upper surfaces of the coloring layer and the light-blocking layer are coated with a material of the bonding layer, a material which has high wettability with respect to the material of the bonding layer is preferably used as the material of the overcoat. For example, an oxide conductive film such as an ITO film or a metal film such as an Ag film which is thin enough to transmit light is preferably used as the overcoat.

As the connector, any of a variety of anisotropic conductive films (ACF), anisotropic conductive pastes (ACP), and the like can be used.

As described above, one embodiment of the present invention can be applied to a variety of devices such as a semiconductor device, a light-emitting device, a display device, and an input-output device.

As examples of the display element, an organic EL element, a liquid crystal element, an electrophoretic element, and a display element using micro electro mechanical systems (MEMS) can be given.

Note that the light-emitting device of one embodiment of the present invention may be used as a display device or as a lighting device. For example, it may be used as a light source such as a backlight or a front light, that is, a lighting device for a display panel.

As described in this embodiment, in one embodiment of the present invention, entry of impurities through a side surface of the light-emitting device can be inhibited because the non-light-emitting portion has a region thinner than the light-emitting portion. Thus, the light-emitting device can be highly reliable.

This embodiment can be combined with any other embodiment as appropriate.

### Embodiment 3

In this embodiment, an input-output device of one embodiment of the present invention will be described with reference to drawings. Note that the above description can be referred to for the components of an input-output device, which are similar to those of the light-emitting device described in Embodiment 2. Although an input-output device including a light-emitting element is described as an example in this embodiment, one embodiment of the present invention is not limited thereto. The input-output device described in this embodiment is also a touch panel.

The input-output devices described in this embodiment each have a region thinner than a display portion in a non-display portion and are thus highly reliable. Portions other than the display portion (light-emitting portion) in the input-output device can be regarded as the non-display portions (non-light-emitting portions). In other words, the non-display portion is provided outside a display portion **301** and a display portion **501** to have a frame-like shape. For example, a driver circuit portion is a non-light-emitting portion.

### Structure Example 1

FIG. **33A** is a top view of the input-output device. FIG. **33B** and FIG. **37A** are cross-sectional views each taken along the dashed-dotted line A-B and dashed-dotted line C-D in FIG. **33A**. Specifically, FIG. **33B** and FIG. **37A** show an application example of the structure example a-3 and an application example of the structure example b-3, respectively. FIG. **33C** is a cross-sectional view taken along the dashed-dotted line E-F in FIG. **33A**.

An input-output device **390** illustrated in FIG. **33A** includes the display portion **301** (serving also as an input portion), a scan line driver circuit **303g(1)**, an imaging pixel driver circuit **303g(2)**, an image signal line driver circuit **303s(1)**, and an imaging signal line driver circuit **303s(2)**.

The display portion **301** includes a plurality of pixels **302** and a plurality of imaging pixels **308**.

The pixel **302** includes a plurality of sub-pixels. Each sub-pixel includes a light-emitting element and a pixel circuit.

The pixel circuits can supply electric power for driving the light-emitting element. The pixel circuits are electrically connected to wirings through which selection signals are supplied. The pixel circuits are also electrically connected to wirings through which image signals are supplied.

The scan line driver circuit **303g(1)** can supply selection signals to the pixels **302**.

The image signal line driver circuit **303s(1)** can supply image signals to the pixels **302**.

A touch sensor can be formed using the imaging pixels **308**. Specifically, the imaging pixels **308** can sense a touch of a finger or the like on the display portion **301**.

The imaging pixels **308** include photoelectric conversion elements and imaging pixel circuits.

The imaging pixel circuits can drive photoelectric conversion elements. The imaging pixel circuits are electrically connected to wirings through which control signals are supplied. The imaging pixel circuits are also electrically connected to wirings through which power supply potentials are supplied.

Examples of the control signal include a signal for selecting an imaging pixel circuit from which a recorded imaging signal is read, a signal for initializing an imaging pixel circuit, and a signal for determining the time for an imaging pixel circuit to sense light.

The imaging pixel driver circuit **303g(2)** can supply control signals to the imaging pixels **308**.

The imaging signal line driver circuit **303s(2)** can read out imaging signals.

As illustrated in FIGS. **33B** and **33C** and FIG. **37A**, the input-output device **390** includes the first flexible substrate **701**, the first bonding layer **703**, the first insulating layer **705**, the second flexible substrate **711**, the second bonding layer **713**, the second insulating layer **715**. The first and second flexible substrates **701** and **711** are attached to each other with a third bonding layer **360**.

The input-output device in FIG. **33B** has a portion where the thickness continuously (smoothly) decreases from the display portion side of the non-display portion to an end portion of the input-output device. In FIG. **37A**, a depression is formed in the non-display portion. In the depression, the thickness of the third bonding layer **360** is small. With the above structure, entry of impurities through a side surface of the input-output device can be inhibited.

The first flexible substrate **701** and the first insulating layer **705** are attached to each other with the first bonding layer **703**. The second flexible substrate **711** and the second

insulating layer **715** are attached to each other with the second bonding layer **713**. Embodiment 2 can be referred to for materials used for the substrates, the bonding layers, and the insulating layers.

Each of the pixels **302** includes the sub-pixel **302R**, a sub-pixel **302G**, and a sub-pixel **302B** (see FIG. **33C**).

For example, the sub-pixel **302R** includes the light-emitting element **350R** and the pixel circuit. The pixel circuit includes a transistor **302t** that can supply electric power to the light-emitting element **350R**. The sub-pixel **302R** further includes an optical element (e.g., a coloring layer **367R** that transmits red light).

The light-emitting element **350R** includes a lower electrode **351R**, an EL layer **353**, and an upper electrode **352**, which are stacked in this order (see FIG. **33C**).

The EL layer **353** includes a first EL layer **353a**, an intermediate layer **354**, and a second EL layer **353b**, which are stacked in this order.

Note that a microcavity structure can be provided for the light-emitting element **350R** so that light with a specific wavelength can be efficiently extracted. Specifically, an EL layer may be provided between a film that reflects visible light and a film that partly reflects and partly transmits visible light, which are provided so that light with a specific wavelength can be efficiently extracted.

The sub-pixel **302R** includes the third bonding layer **360** that is in contact with the light-emitting element **350R** and the coloring layer **367R**. The coloring layer **367R** is positioned in a region overlapping with the light-emitting element **350R**. Accordingly, part of light emitted from the light-emitting element **350R** passes through the third bonding layer **360** and through the coloring layer **367R** and is emitted to the outside of the sub-pixel **302R** as indicated by an arrow in FIG. **33B** or **33C**.

The input-output device **390** includes a light-blocking layer **367BM**. The light-blocking layer **367BM** is provided so as to surround the coloring layer (e.g., the coloring layer **367R**).

The input-output device **390** includes an anti-reflective layer **367p** positioned in a region overlapping with the display portion **301**. As the anti-reflective layer **367p**, a circular polarizing plate can be used, for example.

The input-output device **390** includes an insulating layer **321**. The insulating layer **321** covers the transistor **302t** and the like. Note that the insulating layer **321** can be used as a layer covering unevenness caused by the pixel circuits and the imaging pixel circuits to provide a flat surface. The transistor **302t** and the like are preferably covered with an insulating layer that can inhibit diffusion of impurities to the transistor **302t** and the like.

The input-output device **390** includes a partition **328** that overlaps with an end portion of the lower electrode **351R**. A spacer **329** that controls the gap between the first flexible substrate **701** and the second flexible substrate **711** is provided on the partition **328**.

The image signal line driver circuit **303s(1)** includes a transistor **303t** and a capacitor **303c**. Note that the driver circuit can be formed in the same process and over the same substrate as those of the pixel circuits. As illustrated in FIG. **33B** and FIG. **37A**, the transistor **303t** may include a second gate **304** over the insulating layer **321**. The second gate **304** may be electrically connected to a gate of the transistor **303t**, or different potentials may be supplied to these gates. Alternatively, if necessary, the second gate **304** may be provided for a transistor **308t**, the transistor **302t**, or the like.

The imaging pixels **308** each include a photoelectric conversion element **308p** and an imaging pixel circuit. The

imaging pixel circuit can sense light received by the photoelectric conversion element **308p**. The imaging pixel circuit includes the transistor **308t**. For example, a PIN photodiode can be used as the photoelectric conversion element **308p**.

The input-output device **390** includes a wiring **311** through which a signal is supplied. The wiring **311** is provided with a terminal **319**. An FPC **309** through which a signal such as an image signal or a synchronization signal is supplied is electrically connected to the terminal **319**. A printed wiring board (PWB) may be attached to the FPC **309**.

Note that transistors such as the transistors **302t**, **303t**, and **308t** can be formed in the same process. Alternatively, the transistors may be formed in different processes.

### Structure Example 2

FIGS. **34A** and **34B** are perspective views of an input-output device **505**. FIGS. **34A** and **34B** illustrate only main components for simplicity. FIG. **35A** is a cross-sectional view taken along the dashed-dotted line X1-X2 in FIG. **34A**. FIG. **35A** illustrates an application example of the structure example a-3. As a modification example, FIG. **37B** illustrates an application example of the structure example b-3.

As illustrated in FIGS. **34A** and **34B**, the input-output device **505** includes the display portion **501**, the scan line driver circuit **303g(1)**, a touch sensor **595**, and the like. Furthermore, the input-output device **505** includes the first flexible substrate **701**, the second flexible substrate **711**, and a flexible substrate **590**.

The input-output device **505** includes a plurality of pixels and a plurality of wirings **311**. The plurality of wirings **311** can supply signals to the pixels. The plurality of wirings **311** are arranged to a peripheral portion of the first flexible substrate **701**, and part of the plurality of wirings **311** form the terminal **319**. The terminal **319** is electrically connected to an FPC **509(1)**.

The input-output device **505** includes the touch sensor **595** and a plurality of wirings **598**. The plurality of wirings **598** are electrically connected to the touch sensor **595**. The plurality of wirings **598** are arranged to a peripheral portion of the flexible substrate **590**, and part of the plurality of wirings **598** forms a terminal. The terminal is electrically connected to an FPC **509(2)**. Note that in FIG. **34B**, electrodes, wirings, and the like of the touch sensor **595** provided on the back side of the flexible substrate **590** (the side facing the first flexible substrate **701**) are indicated by solid lines for clarity.

As the touch sensor **595**, for example, a capacitive touch sensor can be used. Examples of the capacitive touch sensor include a surface capacitive touch sensor and a projected capacitive touch sensor. An example of using a projected capacitive touch sensor is described here.

Examples of the projected capacitive touch sensor include a self-capacitive touch sensor and a mutual capacitive touch sensor. The use of a mutual capacitive touch sensor is preferred because multiple points can be sensed simultaneously.

Note that a variety of sensors that can sense the closeness or the contact of a sensing target such as a finger can be used as the touch sensor **595**.

The projected capacitive touch sensor **595** includes electrodes **591** and electrodes **592**. The electrodes **591** are electrically connected to any of the plurality of wirings **598**, and the electrodes **592** are electrically connected to any of the other wirings **598**.

The electrodes **592** each have a shape of a plurality of quadrangles arranged in one direction with one corner of a quadrangle connected to one corner of another quadrangle as illustrated in FIGS. **34A** and **34B**.

The electrodes **591** each have a quadrangular shape and are arranged in a direction intersecting with the direction in which the electrodes **592** extend. Note that the plurality of electrodes **591** are not necessarily arranged in the direction orthogonal to one electrode **592** and may be arranged to intersect with one electrode **592** at an angle of less than 90 degrees.

The wiring **594** intersects with the electrode **592**. The wiring **594** electrically connects two electrodes **591** between which one electrode **592** is positioned. The intersecting area of the electrode **592** and the wiring **594** is preferably as small as possible. Such a structure allows a reduction in the area of a region where the electrodes are not provided, reducing unevenness in light transmittance. As a result, unevenness in luminance of light emitted through the touch sensor **595** can be reduced.

Note that the shapes of the electrodes **591** and the electrodes **592** are not limited to the above-mentioned shapes and can be any of a variety of shapes.

As illustrated in FIG. **35A** and FIG. **37B**, the input-output device **505** includes the first flexible substrate **701**, the first bonding layer **703**, the first insulating layer **705**, the second flexible substrate **711**, the second bonding layer **713**, the second insulating layer **715**. The first and second flexible substrates **701** and **711** are attached to each other with the third bonding layer **360**.

A bonding layer **597** attaches the flexible substrate **590** to the second flexible substrate **711** so that the touch sensor **595** overlaps with the display portion **501**. The bonding layer **597** has a light-transmitting property.

The electrodes **591** and the electrodes **592** are formed using a light-transmitting conductive material. As a light-transmitting conductive material, a conductive oxide such as indium oxide, indium tin oxide, indium zinc oxide, zinc oxide, or zinc oxide to which gallium is added can be used. A film including graphene may be used as well. The film including graphene can be formed, for example, by reducing a film including graphene oxide. As a reducing method, heating or the like can be employed.

Note that as an example of a material for the conductive films such as the electrodes **591**, the electrodes **592**, and the wirings **594**, that is, wirings and electrodes forming a touch panel, a transparent conductive film including indium oxide, tin oxide, zinc oxide, or the like (e.g., ITO) can be given. The resistance of materials used for wirings and electrodes of the touch panel is preferably low. For example, silver, copper, aluminum, a carbon nanotube, graphene, or a metal halide (such as silver halide) may be used. Alternatively, a metal nanowire including a plurality of conductors with an extremely small width (for example, a diameter of several nanometers) may be used. Further alternatively, a metal mesh which is a net-like conductor may be used. For example, an Ag nanowire, a Cu nanowire, an Al nanowire, an Ag mesh, a Cu mesh, or an Al mesh may be used. In the case of using an Ag nanowire for a wiring or an electrode of the touch panel, a visible light transmittance of 89% or more and a sheet resistance of 40  $\Omega$ /square or more and 100  $\Omega$ /square or less can be achieved. Since the above-described metal nanowire, metal mesh, carbon nanotube, graphene, and the like, which are examples of the material that can be used as the wirings and electrodes forming the touch panel,

have high visible light transmittances, they may be used as electrodes of display elements (e.g., a pixel electrode or a common electrode).

The electrodes **591** and the electrodes **592** can be formed by depositing a light-transmitting conductive material on the flexible substrate **590** by a sputtering method and then removing an unneeded portion by a variety of patterning technique such as photolithography.

The electrodes **591** and the electrodes **592** are covered with an insulating layer **593**. Openings reaching the electrodes **591** are formed in the insulating layer **593**, and the wiring **594** electrically connects the adjacent electrodes **591**. A light-transmitting conductive material can be favorably used as the wiring **594** because the aperture ratio of the input-output device can be increased. Moreover, a material with higher conductivity than the conductivities of the electrodes **591** and the electrodes **592** can be favorably used for the wiring **594** because electric resistance can be reduced.

Note that an insulating layer covering the insulating layer **593** and the wiring **594** may be provided to protect the touch sensor **595**.

A connection layer **599** electrically connects the wirings **598** to the FPC **509(2)**.

The display portion **501** includes a plurality of pixels arranged in a matrix. Each pixel has the same structure as Structure Example 1; thus, description is omitted.

As illustrated in FIG. **35B**, the touch panel may include two substrates of the first flexible substrate **701** and the second flexible substrate **711** without including the flexible substrate **590**. The second flexible substrate **711** and the second insulating layer **715** are attached to each other with the second bonding layer **713**, and the touch sensor **595** is provided in contact with the second insulating layer **715**. The coloring layer **367R** and the light-blocking layer **367BM** are provided in contact with the insulating layer **589** that covers the touch sensor **595**. The insulating layer **589** is not necessarily provided, in which case the coloring layer **367R** and the light-blocking layer **367BM** are provided in contact with the wiring **594**.

### Structure Example 3

FIGS. **36A** to **36C** are cross-sectional views of an input-output device **505B**. The input-output device **505B** described in this embodiment is different from the input-output device **505** in Structure Example 2 in that received image data is displayed on the side where the transistors are provided and that the touch sensor is provided on the first flexible substrate **701** side of the display portion. Different structures will be described in detail below, and the above description is referred to for the other similar structures. FIG. **36A** illustrates an application example of the structure example a-3. As a modification example, FIG. **37C** illustrates an application example of the structure example b-3.

The coloring layer **367R** is positioned in a region overlapping with the light-emitting element **350R**. The light-emitting element **350R** illustrated in FIG. **36A** and FIG. **37C** emits light to the side where the transistor **302t** is provided. Accordingly, part of light emitted from the light-emitting element **350R** passes through the coloring layer **367R** and is emitted to the outside of the input-output device **505B** as indicated by an arrow in FIG. **36A** or FIG. **37C**.

The input-output device **505B** includes the light-blocking layer **367BM** on the light extraction side. The light-blocking layer **367BM** is provided so as to surround the coloring layer (e.g., the coloring layer **367R**).

The touch sensor **595** is provided not on the second flexible substrate **711** side but on the first flexible substrate **701** side (see FIG. **36A** and FIG. **37C**).

The bonding layer **597** attaches the flexible substrate **590** to the first flexible substrate **701** so that the touch sensor **595** overlaps with the display portion. The bonding layer **597** has a light-transmitting property.

Note that a structure in the case of using bottom-gate transistors in the display portion **501** is illustrated in FIGS. **36A** and **36B** and FIG. **37C**.

For example, a semiconductor layer containing an oxide semiconductor, amorphous silicon, or the like can be used in the transistor **302t** and the transistor **303t** illustrated in FIG. **36A** and FIG. **37C**.

For example, a semiconductor layer containing polycrystalline silicon can be used in the transistor **302t** and the transistor **303t** illustrated in FIG. **36B**.

A structure in the case of using top-gate transistors is illustrated in FIG. **36C**.

For example, a semiconductor layer containing polycrystalline silicon, a single crystal silicon film that is transferred from a single crystal silicon substrate, or the like can be used in the transistor **302t** and the transistor **303t** illustrated in FIG. **36C**.

This embodiment can be combined with any other embodiment as appropriate.

#### Embodiment 4

In this embodiment, electronic devices and lighting devices of embodiments of the present invention will be described with reference to drawings.

With the use of the light-emitting device, the display device, the input-output device, or the like of one embodiment of the present invention, an electronic device or a lighting device with high reliability can be fabricated. Furthermore, with the use of the light-emitting device, the display device, the input-output device, or the like of one embodiment of the present invention, an electronic device or a lighting device with high reliability that has a curved surface or flexibility can be fabricated.

Examples of electronic devices include a television set (also referred to as a television or a television receiver), a monitor of a computer or the like, a digital camera, a digital video camera, a digital photo frame, a mobile phone (also referred to as a cellular phone or a mobile phone device), a portable game console, a portable information terminal, an audio reproducing device, and a large game machine such as a pinball machine.

The electronic device or the lighting device of one embodiment of the present invention has flexibility and therefore can be incorporated along a curved inside/outside wall surface of a house or a building or a curved interior/exterior surface of a car.

Furthermore, the electronic device of one embodiment of the present invention may include a secondary battery. It is preferable that the secondary battery be capable of being charged by non-contact power transmission.

Examples of the secondary battery include a lithium ion secondary battery such as a lithium polymer battery using a gel electrolyte (lithium ion polymer battery), a nickel-hydride battery, a nickel-cadmium battery, an organic radical battery, a lead-acid battery, an air secondary battery, a nickel-zinc battery, and a silver-zinc battery.

The electronic device of one embodiment of the present invention may include an antenna. When a signal is received by the antenna, the electronic device can display an image,

data, or the like on a display portion. When the electronic device includes the antenna and a secondary battery, the antenna may be used for contactless power transmission.

FIGS. **38A**, **38B**, **38C1**, **38C2**, **38D**, and **38E** illustrate examples of an electronic device including a display portion **7000** with a curved surface. The display surface of the display portion **7000** is curved, and images can be displayed on the curved display surface. The display portion **7000** may be flexible.

The display portion **7000** is formed using the light-emitting device, the display device, the input-output device, or the like of one embodiment of the present invention.

One embodiment of the present invention makes it possible to provide an electronic device having a curved display portion and high reliability.

FIG. **38A** illustrates an example of a mobile phone. A mobile phone **7100** includes a housing **7101**, the display portion **7000**, operation buttons **7103**, an external connection port **7104**, a speaker **7105**, a microphone **7106**, and the like.

The mobile phone **7100** illustrated in FIG. **38A** includes a touch sensor in the display portion **7000**. Moreover, operations such as making a call and inputting characters can be performed by touch on the display portion **7000** with a finger, a stylus, or the like.

With the operation buttons **7103**, power ON or OFF can be switched. In addition, types of images displayed on the display portion **7000** can be switched; switching images from a mail creation screen to a main menu screen, for example.

FIG. **38B** illustrates an example of a television set. In the television set **7200**, the display portion **7000** is incorporated into the housing **7201**. Here, the housing **7201** is supported by a stand **7203**.

The television set **7200** illustrated in FIG. **38B** can be operated with an operation switch of the housing **7201** or a separate remote controller **7211**. The display portion **7000** may include a touch sensor. The television set **7200** can be operated by touching the display portion **7000** with a finger or the like. The remote controller **7211** may be provided with a display portion for displaying data output from the remote controller **7211**. With operation keys or a touch panel of the remote controller **7211**, channels and volume can be controlled and images displayed on the display portion **7000** can be controlled.

The television set **7200** is provided with a receiver, a modem, and the like. A general television broadcast can be received with the receiver. When the television set is connected to a communication network with or without wires via the modem, one-way (from a transmitter to a receiver) or two-way (between a transmitter and a receiver or between receivers) data communication can be performed.

FIGS. **38C1**, **38C2**, **38D**, and **38E** illustrate examples of a portable information terminal. Each of the portable information terminals includes a housing **7301** and the display portion **7000**. Each of the portable information terminals may also include an operation button, an external connection port, a speaker, a microphone, an antenna, a battery, or the like. The display portion **7000** is provided with a touch sensor. An operation of the portable information terminal can be performed by touching the display portion **7000** with a finger, a stylus, or the like.

FIG. **38C1** is a perspective view of a portable information terminal **7300**. FIG. **38C2** is a top view of the portable information terminal **7300**. FIG. **38D** is a perspective view of a portable information terminal **7310**. FIG. **38E** is a perspective view of a portable information terminal **7320**.

Each of the portable information terminals illustrated in this embodiment functions as, for example, one or more of a telephone set, a notebook, and an information browsing system. Specifically, the portable information terminals each can be used as a smartphone. Each of the portable information terminals described in this embodiment is capable of executing a variety of applications such as mobile phone calls, e-mailing, reading and editing texts, music reproduction, Internet communication, and a computer game, for example.

The portable information terminals **7300**, **7310**, and **7320** can display characters and image data on its plurality of surfaces. For example, as illustrated in FIGS. **38C1** and **38D**, three operation buttons **7302** can be displayed on one surface, and data **7303** indicated by a rectangle can be displayed on another surface. FIGS. **38C1** and **38C2** illustrate an example in which data is displayed at the top of the portable information terminal. FIG. **38D** illustrates an example in which data is displayed on the side of the portable information terminal. Data may be displayed on three or more surfaces of the portable information terminal. FIG. **38E** illustrates an example where data **7304**, data **7305**, and data **7306** are displayed on different surfaces.

Examples of the data include notification from a social networking service (SNS), display indicating reception of e-mail or an incoming call, the title of e-mail or the like, the sender of e-mail or the like, the date, the time, remaining battery, the reception strength of an antenna, and the like. Instead of the data, an operation button, an icon, or the like may be displayed on the position where the data is displayed.

For example, a user of the portable information terminal **7300** can see the display (here, the data **7303**) with the portable information terminal **7300** put in a breast pocket of his/her clothes.

Specifically, a caller's phone number, name, or the like of an incoming call is displayed in a position that can be seen from above the portable information terminal **7300**. Thus, the user can see the display without taking out the portable information terminal **7300** from the pocket and decide whether to answer the call.

FIGS. **38F** to **38H** each illustrate an example of a lighting device having a curved light-emitting portion.

The light-emitting portion included in each of the lighting devices illustrated in FIGS. **38F** to **38H** can be manufactured using the light-emitting device or the like of one embodiment of the present invention.

One embodiment of the present invention makes it possible to provide a lighting device having a curved light-emitting portion and high reliability.

A lighting device **7400** illustrated in FIG. **38F** includes a light-emitting portion **7402** having a wave-shaped light-emitting surface, which is a good-design lighting device.

A light-emitting portion **7412** included in the lighting device **7410** illustrated in FIG. **38G** has two convex-curved light-emitting portions symmetrically placed. Thus, all directions can be illuminated with the lighting device **7410** as a center.

A lighting device **7420** illustrated in FIG. **38H** includes a concave-curved light-emitting portion **7422**. This is suitable for illuminating a specific range because light emitted from the light-emitting portion **7422** is collected to the front of the lighting device **7420**. In addition, with this structure, a shadow is less likely to be produced.

The light-emitting portion included in each of the lighting devices **7400**, **7410** and **7420** may be flexible. The light-emitting portion may be fixed on a plastic member, a

movable frame, or the like so that an emission surface of the light-emitting portion can be curved freely depending on the intended use.

The lighting devices **7400**, **7410**, and **7420** each include a stage **7401** provided with an operation switch **7403** and a light-emitting portion supported by the stage **7401**.

Note that although the lighting device in which the light-emitting portion is supported by the stage is described as an example here, a housing provided with a light-emitting portion can be fixed on a ceiling or suspended from a ceiling. Since the light-emitting surface can be curved, the light-emitting surface is curved to have a depressed shape, whereby a particular region can be brightly illuminated, or the light-emitting surface is curved to have a projecting shape, whereby a whole room can be brightly illuminated.

FIGS. **39A1**, **39A2**, and **39B** to **39I** illustrate examples of a portable information terminal including a display portion **7001** having flexibility.

The display portion **7001** is manufactured using the light-emitting device, the display device, the input-output device, or the like of one embodiment of the present invention. For example, a light-emitting device, a display device, or an input-output device that can be bent with a radius of curvature of greater than or equal to 0.01 mm and less than or equal to 150 mm can be used. The display portion **7001** may include a touch sensor so that the portable information terminal can be operated by touching the display portion **7001** with a finger or the like.

One embodiment of the present invention makes it possible to provide a highly reliable electronic device including a display portion having flexibility.

FIG. **39A1** is a perspective view illustrating an example of a portable information terminal and FIG. **39A2** is a side view illustrating an example of the portable information terminal. A portable information terminal **7500** includes a housing **7501**, the display portion **7001**, a display portion tab **7502**, operation buttons **7503**, and the like.

The portable information terminal **7500** includes a rolled flexible display portion **7001** in the housing **7501**.

The portable information terminal **7500** can receive a video signal with a control portion incorporated therein and can display the received video on the display portion **7001**. The portable information terminal **7500** incorporates a battery. A terminal portion for connecting a connector may be included in the housing **7501** so that a video signal or power can be directly supplied from the outside with a wiring.

By pressing the operation buttons **7503**, power ON/OFF, switching of displayed videos, and the like can be performed. Although FIGS. **39A1**, **39A2**, and **39B** illustrate an example where the operation buttons **7503** are positioned on a side surface of the portable information terminal **7500**, one embodiment of the present invention is not limited thereto. The operation buttons **7503** may be placed on a display surface (a front surface) or a rear surface of the portable information terminal **7500**.

FIG. **39B** illustrates the portable information terminal **7500** in a state where the display portion **7001** is pulled out. Videos can be displayed on the display portion **7001** in this state. In addition, the portable information terminal **7500** may perform different displays in the state where part of the display portion **7001** is rolled as shown in FIG. **39A1** and in the state where the display portion **7001** is pulled out with the display portion tab **7502** as shown in FIG. **39B**. For example, in the state shown in FIG. **39A1**, the rolled portion of the display portion **7001** is put in a non-display state, which results in a reduction in power consumption of the portable information terminal **7500**.

A reinforcement frame may be provided for a side portion of the display portion 7001 so that the display portion 7001 has a flat display surface when pulled out.

Note that in addition to this structure, a speaker may be provided for the housing so that sound is output with an audio signal received together with a video signal.

FIGS. 39C to 39E illustrate an example of a foldable portable information terminal. FIG. 39C illustrates a portable information terminal 7600 that is opened. FIG. 39D illustrates the portable information terminal 7600 that is being opened or being folded. FIG. 39E illustrates the portable information terminal 7600 that is folded. The portable information terminal 7600 is highly portable when folded, and is highly browsable when opened because of a large seamless display area.

The display portion 7001 is supported by three housings 7601 joined together by hinges 7602. By folding the portable information terminal 7600 at a connection portion between two housings 7601 with the hinges 7602, the portable information terminal 7600 can be reversibly changed in shape from an opened state to a folded state.

FIGS. 39F and 39G illustrate an example of a foldable portable information terminal. FIG. 39F illustrates a portable information terminal 7650 that is folded so that the display portion 7001 is on the inside. FIG. 39G illustrates the portable information terminal 7650 that is folded so that the display portion 7001 is on the outside. The portable information terminal 7650 includes the display portion 7001 and a non-display portion 7651. When the portable information terminal 7650 is not used, the portable information terminal 7650 is folded so that the display portion 7001 is on the inside, whereby the display portion 7001 can be prevented from being contaminated or damaged.

FIG. 39H illustrates an example of a flexible portable information terminal. A portable information terminal 7700 includes a housing 7701 and the display portion 7001. The portable information terminal 7700 may include buttons 7703a and 7703b which serve as input means, speakers 7704a and 7704b which serve as sound output means, an external connection port 7705, a microphone 7706, or the like. A flexible battery 7709 can be mounted on the portable information terminal 7700. The battery 7709 may be arranged to overlap with the display portion 7001, for example.

The housing 7701, the display portion 7001, and the battery 7709 are flexible. Thus, it is easy to curve the portable information terminal 7700 into a desired shape or to twist the portable information terminal 7700. For example, the portable information terminal 7700 can be curved so that the display portion 7001 is on the inside or in the outside. The portable information terminal 7700 can be used in a rolled state. Since the housing 7701 and the display portion 7001 can be changed in shape freely in this manner, the portable information terminal 7700 is less likely to be broken even when the portable information terminal 7700 falls down or external stress is applied to the portable information terminal 7700.

The portable information terminal 7700 can be used effectively in various situations because the portable information terminal 7700 is lightweight. For example, the portable information terminal 7700 can be used in the state where the upper portion of the housing 7701 is suspended by a clip or the like, or in the state where the housing 7701 is fixed to a wall by magnets or the like.

FIG. 39I illustrates an example of a wrist-watch-type portable information terminal. The portable information terminal 7800 includes a band 7801, the display portion

7001, an input-output terminal 7802, operation buttons 7803, and the like. The band 7801 has a function of a housing. A flexible battery 7805 can be mounted on the portable information terminal 7800. The battery 7805 may overlap with the display portion 7001 and the band 7801, for example.

The band 7801, the display portion 7001, and the battery 7805 have flexibility. Thus, the portable information terminal 7800 can be easily curved to have a desired shape.

With the operation buttons 7803, a variety of functions such as time setting, ON/OFF of the power, ON/OFF of wireless communication, setting and cancellation of silent mode, and setting and cancellation of power saving mode can be performed. For example, the functions of the operation button 7803 can be set freely by the operating system incorporated in the portable information terminal 7800.

By touching an icon 7804 displayed on the display portion 7001 with a finger or the like, application can be started.

The portable information terminal 7800 can employ near field communication that is a communication method based on an existing communication standard. In that case, for example, mutual communication between the portable information terminal 7800 and a headset capable of wireless communication can be performed, and thus hands-free calling is possible.

The portable information terminal 7800 may include the input-output terminal 7802. In the case where the input-output terminal 7802 is included, data can be directly transmitted to and received from another information terminal via a connector. Charging through the input-output terminal 7802 is also possible. Note that charging of the portable information terminal described as an example in this embodiment can be performed by non-contact power transmission without using the input-output terminal.

FIG. 40A is an external view of an automobile 9700. FIG. 40B illustrates a driver's seat of the automobile 9700. The automobile 9700 includes a car body 9701, wheels 9702, a dashboard 9703, lights 9704, and the like. The light-emitting device, the display device, the input-output device, or the like of one embodiment of the present invention can be used in a display portion or the like of the automobile 9700. For example, the light-emitting device, the display device, the input-output device, or the like of one embodiment of the present invention can be used in display portions 9710 to 9715 illustrated in FIG. 40B.

The display portion 9710 and the display portion 9711 are display devices provided in an automobile windshield. The light-emitting device, the display device, the input-output device, or the like of one embodiment of the present invention can be a see-through device, through which the opposite side can be seen, by using a light-transmitting conductive material for its electrodes and wirings. The see-through display portion 9710 and the see-through display portion 9711 do not hinder driver's vision during driving of the automobile 9700. Therefore, the light-emitting device, the display device, the input-output device, or the like of one embodiment of the present invention can be provided in the windshield of the automobile 9700. Note that in the case where a transistor or the like for driving the light-emitting device, the display device, the input-output device, or the like is provided, a transistor having a light-transmitting property, such as an organic transistor using an organic semiconductor material or a transistor using an oxide semiconductor, is preferably used.

The display portion 9712 is a display device provided on a pillar portion. For example, an image taken by an imaging unit provided in the car body is displayed on the display

portion 9712, whereby the view hindered by the pillar portion can be compensated. The display portion 9713 is a display device provided on the dashboard. For example, an image taken by an imaging unit provided in the car body is displayed on the display portion 9713, whereby the view hindered by the dashboard can be compensated. That is, by displaying an image taken by an imaging unit provided on the outside of the automobile, blind areas can be eliminated and safety can be increased. Displaying an image to compensate for the area which a driver cannot see makes it possible for the driver to confirm safety easily and comfortably.

FIG. 40C illustrates the inside of a car in which bench seats are used for a driver seat and a front passenger seat. A display portion 9721 is a display device provided in a door portion. For example, an image taken by an imaging unit provided in the car body is displayed on the display portion 9721, whereby the view hindered by the door can be compensated. A display portion 9722 is a display device provided in a steering wheel. A display portion 9723 is a display device provided in the middle of a seating face of the bench seat. Note that the display device can be used as a seat heater by providing the display device on the seating face or backrest and by using heat generation of the display device as a heat source.

The display portion 9714, the display portion 9715, and the display portion 9722 can provide a variety of kinds of data such as navigation data, a speedometer, a tachometer, a mileage, a fuel meter, a gearshift indicator, and air-condition setting. The content, layout, or the like of the display on the display portions can be changed freely by a user as appropriate. The data listed above can also be displayed on the display portions 9710 to 9713, 9721, and 9723. The display portions 9710 to 9715 and 9721 to 9723 can also be used as lighting devices. The display portions 9710 to 9715 and 9721 to 9723 can also be used as heating devices.

The display portion in which the light-emitting device, display device, input-output device, or the like of one embodiment of the present invention is used may have a flat surface.

FIG. 40D illustrates a portable game console including a housing 9801, a housing 9802, a display portion 9803, a display portion 9804, a microphone 9805, a speaker 9806, an operation key 9807, a stylus 9808, and the like.

The portable game console shown in FIG. 40D includes two display portions 9803 and 9804. Note that the number of display portions of an electronic device of one embodiment of the present invention is not limited to two and can be one or three or more as long as at least one display portion includes the light-emitting device, the display device, the input-output device, or the like of one embodiment of the present invention.

FIG. 40E illustrates a laptop personal computer, which includes a housing 9821, a display portion 9822, a keyboard 9823, a pointing device 9824, and the like.

This embodiment can be combined with any other embodiment as appropriate.

#### Example 1

In this example, description will be made on a sample fabricated with the use of one embodiment of the present invention.

The sample in this example was designed with a light-emitting device in mind. The sample had the structure of the light-emitting device described in Embodiment 2, but some

components (the EL layer and the upper electrode) of the light-emitting element were not formed.

The sample had a region corresponding to a light-emitting portion, and a region corresponding to a non-light-emitting portion is provided outside the light-emitting portion to have a frame-like shape.

First, a method for manufacturing the sample is described with reference to FIGS. 8A to 8D, FIG. 9A, FIGS. 26B and 26C, and FIGS. 41A and 41B.

As illustrated in FIG. 8A, the separation layer 203 was formed over the formation substrate 201, and the insulating layer 205 was formed over the separation layer 203. A 0.7-mm-thick glass substrate was used as the formation substrate 201. A stacked-layer structure including a tungsten film and a tungsten oxide film was used as the separation layer 203. A stacked-layer structure including a silicon oxynitride film and a silicon nitride film was used as the insulating layer 205. The functional layer 206 included a transistor using an oxide semiconductor.

With reference to FIGS. 26B and 26C, a specific structure of a layer to be separated (the insulating layer 205 and the functional layer 206 in FIG. 8A) that was fabricated over the separation layer 203 in this example is described. As the layer to be separated, the insulating layer 705, the transistor 820, the insulating layer 815, the insulating layer 817a, the conductive layer 856, the insulating layer 817b, the lower electrode 831, the optical adjustment layer 832, the insulating layer 821, and the spacer 823 were formed.

In addition, as illustrated in FIG. 8B, the separation layer 223 was formed over the formation substrate 221, and the insulating layer 225 was formed over the separation layer 223. A glass substrate was used as the formation substrate 221. A stacked-layer structure including a tungsten film and a tungsten oxide film was used as the separation layer 223. A stacked-layer structure including a silicon oxynitride film and a silicon nitride film was used as the insulating layer 225.

With reference to FIG. 26B, a specific structure of the layer to be separated (the insulating layer 225 and the functional layer 226 in FIG. 8B) that was fabricated over the separation layer 223 in this example is described. As the layer to be separated, the insulating layer 715, the light-blocking layer 847, and the coloring layer 845 were formed.

Furthermore, under a reduced-pressure atmosphere, as illustrated in FIG. 8C, the formation substrate 201 and the formation substrate 221 overlapped with each other with the bonding layer 207 and the frame-like partition 209 provided therebetween. A thermosetting resin was used for the bonding layer 207, and an ultraviolet curable resin was used for the partition 209. The bonding layer 207 was formed by a printing method, and the partition 209 was formed by a dispensing method. Note that the bonding layer 207 was formed to a thickness of greater than or equal to approximately 5  $\mu\text{m}$  and less than or equal to approximately 8  $\mu\text{m}$ .

The bonding layer 207 and the partition 209 were positioned as illustrated in FIG. 41A. The bonding layer 207 was formed to overlap with the light-emitting portion 804 and the driver circuit portion 806.

In this example, the bonding layer 207 was provided such that an end portion thereof was on an inner side of end portions of the driver circuit portion 806 and the light-emitting portion 804.

In this example, the bonding layer 207 was formed such that the non-light-emitting portion had, on three sides of the sample, a portion with a thickness smaller than that of the light-emitting portion. As illustrated in FIG. 41A, the bonding layer 207 was provided such that an end portion of the

bonding layer 207 was on an inner side of three sides of the light-emitting portion 804 other than the side thereof adjacent to the driver circuit portion 806.

The bonding layer 207 overlapped with two sides of the driver circuit portion 806 in this example; however, in the case where the non-light-emitting portion has a portion with a thickness smaller than that of the light-emitting portion on all the four sides of the sample, for example, the bonding layer 207 may overlap with only one side of the driver circuit portion 806 (the side adjacent to the light-emitting portion 804) as illustrated in FIG. 41B.

In the case where the bonding layer 207 is provided as illustrated in FIG. 41A or 41B, the difference between the thickness of the non-light-emitting portion and that of the light-emitting portion can be increased as compared to the case where end portions of the bonding layer 207 are provided on an outer side of end portions of the driver circuit portion 806 and the light-emitting portion 804 as illustrated in FIG. 41C. The plan layout or thickness of the bonding layer is appropriately adjusted in accordance with the size of the sample or the viscosity of an adhesive.

The partition 209 was formed on an outer side of the light-emitting portion 804 and the driver circuit portion 806. The partition 209 was formed along the periphery of the substrate to have a frame-like shape. The partition 209 was provided so as not to be in contact with the bonding layer 207, with a gap left therebetween.

Next, the formation substrate 201 and the formation substrate 221 were exposed to an air atmosphere and irradiated with ultraviolet light, so that the partition 209 was cured; then, the bonding layer 207 was cured by heating.

After that, a separation starting point was formed by laser light irradiation, and the insulating layer 205 and the formation substrate 201 were separated from each other (FIG. 9A).

A photograph of the sample at this stage is shown in FIG. 42A. The photograph in FIG. 42A was taken from the insulating layer 205 side in FIG. 9A. FIG. 42B shows an enlarged view of a lower left portion of the light-emitting portion 804 in FIG. 42A.

As shown in FIGS. 42A and 42B, interference fringes were observed outside the light-emitting portion 804. It was thus found that outside the light-emitting portion 804, the thickness of the sample changed toward an end portion thereof. No interference fringe was observed in the light-emitting portion 804. Cross-sectional observation did not show a portion where the thickness of the sample is different considerably from that in other portions. Therefore, the non-light-emitting portion presumably had a portion where the thickness smoothly (continuously) changed.

The results of this example showed that one embodiment of the present invention enables the light-emitting portion of the light-emitting device to have a uniform thickness and to form a portion thinner than the light-emitting portion in the non-light-emitting portion. It was thus suggested that entry of moisture and the like through an end portion of the light-emitting device can be inhibited and high reliability can be achieved without impairing display quality of the light-emitting device.

#### Example 2

In this example, description will be made on a sample fabricated with the use of one embodiment of the present invention. The sample fabricated in this example corresponds to the structure example b-3 (FIGS. 16A and 16B).

First, a method for manufacturing the sample is described with reference to FIGS. 16A and 16B, FIGS. 19A and 19B, FIGS. 21A to 21D, and FIGS. 26B and 26C.

As illustrated in FIG. 21A, the separation layer 203 was formed over the formation substrate 201, and the insulating layer 205 was formed over the separation layer 203. A 0.7-mm-thick glass substrate was used as the formation substrate 201. A stacked-layer structure including a tungsten film and a tungsten oxide film was used as the separation layer 203. A stacked-layer structure including a silicon oxynitride film and a silicon nitride film was used as the insulating layer 205. The functional layer 206 included a transistor using an oxide semiconductor and an organic EL element. Although not illustrated in FIG. 21A, the functional layer 204 was also formed over the insulating layer 205 (see FIG. 16A). The functional layer 204 included a transistor using an oxide semiconductor.

With reference to FIGS. 26B and 26C, a specific structure of a layer to be separated (the insulating layer 205 and the functional layer 206 in FIG. 21A) that was fabricated over the separation layer 203 in this example is described. As the layer to be separated, the insulating layer 705, the transistor 820, the insulating layer 815, the insulating layer 817a, the conductive layer 856, the insulating layer 817b, the lower electrode 831, the optical adjustment layer 832, the insulating layer 821, the spacer 823, the EL layer 833, and the upper electrode 835 were formed.

In addition, as illustrated in FIG. 21B, the separation layer 223 was formed over the formation substrate 221, and the insulating layer 225 was formed over the separation layer 223.

A 0.7-mm-thick glass substrate was used as the formation substrate 221. A stacked-layer structure including a tungsten film and a tungsten oxide film was used as the separation layer 223. A stacked-layer structure including a silicon oxynitride film and a silicon nitride film was used as the insulating layer 225.

With reference to FIG. 26B, a specific structure of the layer to be separated (the insulating layer 225 and the functional layer 226 in FIG. 21B) that was fabricated over the separation layer 223 in this example is described. As the layer to be separated, the insulating layer 715, the light-blocking layer 847, and the coloring layer 845 were formed.

Furthermore, under a reduced-pressure atmosphere, as illustrated in FIG. 21C, the formation substrate 201 and the formation substrate 221 overlapped with each other with the bonding layer 207, the frame-like partition 242, and the frame-like temporary sealing layer 244 provided therebetween. A thermosetting resin was used for the bonding layer 207, and an ultraviolet curable resin was used for the frame-like partition 242 and the frame-like temporary sealing layer 244.

The frame-like temporary sealing layer 244 was cured by irradiation with ultraviolet light.

Next, the formation substrate 201 and the formation substrate 221 were exposed to an air atmosphere, and pressure application was performed using a hot press as illustrated in FIG. 19A.

Quartz substrates were used as the substrate 2100a and the substrate 2100b. A glass substrate was used as the substrate 2101. The projection 2102 was formed by curing of a resin. The projection 2102 was formed over the substrate 2101 to have a frame-like shape as illustrated in FIG. 19B. The projection 2102 had a width of approximately 1 mm and a height of approximately 0.1 mm.

With the hot press, a load of 1.0 t was applied to the light-emitting device 10 and the temperature was then raised



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to 100° C. using a heat source, so that pressure application and heating were performed for 1 hour.

Next, a separation starting point was formed by laser light irradiation, the insulating layer **205** and the formation substrate **201** were separated from each other, and the substrate **251** was attached to the exposed insulating layer **205** with the use of the bonding layer **253**. A thermosetting resin was used for the bonding layer **253**, which was cured by heating.

Next, a separation starting point was formed by cutting four sides of the substrate **251** with a cutter, the insulating layer **225** and the formation substrate **221** were separated from each other, and the substrate **259** was attached to the exposed insulating layer **225** with the use of the bonding layer **257**. A thermosetting resin was used for the bonding layer **257**, which was cured by heating.

In the above manner, the light-emitting device illustrated in FIGS. **16A** and **16B** was fabricated.

Interference fringes were observed in the portion to which pressure was applied and the vicinity thereof in the non-light-emitting portion of the light-emitting device fabricated in this example. It was thus found that in the non-light-emitting portion, the thickness changed. The portion where interference fringes were formed had a width of approximately 2 mm. No interference fringe was observed in the light-emitting portion.

Cross-sectional observation of the light-emitting device fabricated in this example was performed. The cross-sectional observation was performed with the use of a scanning electron microscope (SEM). FIGS. **43A** and **43B** show cross-sectional observation images of the portion of the non-light-emitting portion to which pressure was applied and the vicinity thereof. FIG. **43C** shows a cross-sectional observation image of the non-light-emitting portion in a portion closer to the light-emitting portion than the portion to which pressure was applied was. FIG. **44A** shows a cross-sectional observation image of the light-emitting portion. FIG. **44B** shows a cross-sectional observation image of the non-light-emitting portion in a portion closer to an end portion of the light-emitting portion than the portion to which pressure was applied was.

The thicknesses of the bonding layer **207** are also shown in FIGS. **43A** to **43C** and FIGS. **44A** and **44B**. As can be observed in FIGS. **43A** to **43C**, the thickness of the bonding layer **207** in the non-light-emitting portion was different by location. It was found that while having a thickness of approximately 8.7 μm away from the portion to which pressure was applied, the bonding layer **207** had a thickness as small as approximately 2.3 μm in the portion to which pressure was applied. As shown in FIG. **44A**, the bonding layer **207** had a thickness of approximately 11.6 μm in the light-emitting portion. In addition, as shown in FIG. **44B**, in the non-light-emitting portion in the portion closer to an end portion of the light-emitting device than the portion to which pressure was applied was, the bonding layer **207** had a thickness of 49.6 μm, which was much larger than the thicknesses of other portions. It was thus suggested that the light-emitting device had a larger thickness in an end portion than in the light-emitting portion (see FIG. **16C**).

Note that in the light-emitting device fabricated in this example, light was emitted from the entire surface. Moreover, no shrinkage was observed and light was emitted from the entire surface even after a preservation test where the light-emitting device fabricated in this example was preserved at a temperature of 65° C. and a humidity of 95% for 250 hours.

The results of this example showed that one embodiment of the present invention enables the light-emitting portion of

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the light-emitting device to have a uniform thickness and to form a portion thinner than the light-emitting portion in the non-light-emitting portion. In addition, no shrinkage was observed even after the light-emitting device of one embodiment of the present invention was preserved at high temperature and high humidity for 250 hours. It can be presumed that entry of moisture and the like through an end portion of the light-emitting device can be inhibited and high reliability can be achieved without impairing display quality of the light-emitting device.

### Example 3

In this example, description will be made on a sample fabricated with the use of one embodiment of the present invention.

The sample fabricated in this example had the structure illustrated in FIGS. **45B** and **45C**. FIG. **45B** is a cross-sectional view taken along the dashed-dotted line **A1-A2** in FIG. **11A**. FIG. **45C** is a cross-sectional view taken along the dashed-dotted line **A3-A4** in FIG. **11A**.

First, a method for manufacturing the sample is described with reference to FIGS. **21A** to **21C**, FIG. **45A**, and FIGS. **46A** and **46B**.

As illustrated in FIG. **21A**, the separation layer **203** was formed over the formation substrate **201**, and the insulating layer **205** was formed over the separation layer **203**. A 0.7-mm-thick glass substrate was used as the formation substrate **201**. A stacked-layer structure including a tungsten film and a tungsten oxide film was used as the separation layer **203**. A stacked-layer structure including a silicon oxynitride film and a silicon nitride film was used as the insulating layer **205**. The functional layer **206** included a transistor using an oxide semiconductor and an organic EL element. Although not illustrated in FIG. **21A**, the functional layer **204** was also formed over the insulating layer **205** (see FIG. **45B**). The functional layer **204** included a transistor using an oxide semiconductor.

In addition, as illustrated in FIG. **21B**, the separation layer **223** was formed over the formation substrate **221**, and the insulating layer **225** was formed over the separation layer **223**. A 0.7-mm-thick glass substrate was used as the formation substrate **221**. A stacked-layer structure including a tungsten film and a tungsten oxide film was used as the separation layer **223**. A stacked-layer structure including a silicon oxynitride film and a silicon nitride film was used as the insulating layer **225**.

A layer to be separated formed in this example had a structure similar to that described in Example 2.

Furthermore, under a reduced-pressure atmosphere, as illustrated in FIG. **21C**, the formation substrate **201** and the formation substrate **221** overlapped with each other with the bonding layer **207**, the frame-like partition **242**, and the frame-like temporary sealing layer **244** provided therebetween. A thermosetting resin was used for the bonding layer **207**, and an ultraviolet curable resin was used for the frame-like partition **242** and the frame-like temporary sealing layer **244**.

The frame-like temporary sealing layer **244** was cured by irradiation with ultraviolet light.

Next, the formation substrate **201** and the formation substrate **221** were exposed to an air atmosphere, and pressure application was performed using a hot press as illustrated in FIG. **46A**. The structure of the hot press illustrated in FIG. **46A** is the same as that in FIG. **19A** except for the shape of a projection formed on the substrate **2101**.

Quartz substrates were used as the substrate **2100a** and the substrate **2100b**. A glass substrate was used as the substrate **2101**. A projection **2102a** and a projection **2102b** were formed by curing of a resin.

FIG. **46B** is a top view of the substrate **2101**. The projection **2102a** and the projection **2102b** were each formed over the substrate **2101** to have a frame-like shape. The projection **2102a** and the projection **2102b** each had a width of approximately 1 mm and a height of approximately 0.05 mm. The gap between the projection **2102a** and the projection **2102b** was approximately 1.5 mm. In FIG. **46B**, the light-emitting portion **804** and the conductive layer **208** included in the light-emitting device **10** and overlapping with the substrate **2101** are indicated by dotted lines. The light-emitting device **10** was to be cut along dashed-two dotted lines shown in FIG. **46B**.

With the hot press, a load of 1.0 t was applied to the light-emitting device **10** and the temperature was then raised to 100° C. using a heat source, so that pressure application and heating were performed for 1 hour. FIG. **45A** shows a schematic cross-sectional view of the light-emitting device **10** that was changed in shape by the pressure application and heating. By the pressure application and heating, a thin portion was formed in the non-light-emitting portion of the light-emitting device **10**. Since a thermosetting resin was used for forming the bonding layer **207**, the bonding layer **207** was cured by the heating.

Next, a separation starting point was formed by laser light irradiation, the insulating layer **205** and the formation substrate **201** were separated from each other, and the substrate **251** was attached to the exposed insulating layer **205** with the use of the bonding layer **253**. A thermosetting resin was used for the bonding layer **253**, which was cured by heating.

Next, a separation starting point was formed by cutting four sides of the substrate **251** with a cutter, the insulating layer **225** and the formation substrate **221** were separated from each other, and the substrate **259** was attached to the exposed insulating layer **225** with the use of the bonding layer **257**. A thermosetting resin was used for the bonding layer **257**, which was cured by heating.

Then, the light-emitting device **10** was cut along the dashed-two dotted lines shown in FIG. **46B**, whereby the light-emitting device illustrated in FIGS. **45B** and **45C** was fabricated. The completed light-emitting device **10** had a portion whose thickness was reduced with the projection **2102a**. On three sides of the completed light-emitting device **10**, a portion whose thickness was reduced with the projection **2102b** was located at an end portion.

FIG. **47A** is a photograph showing a light-emitting state of the light-emitting device fabricated in this example. With the use of one embodiment of the present invention, light was emitted from the entire surface of the light-emitting device as shown in FIG. **47A**.

The light-emitting device fabricated in this example was preserved at a temperature of 65° C. and a humidity of 95%.

Note that it is difficult to observe shrinkage when a driver transistor operates in a saturation region because the threshold value of the driver transistor is shifted negatively as a light-emitting element degrades, leading to an increased luminance of the light-emitting element.

In view of the above, in a period from 750 hours to 1500 hours after the start of the preservation test, the driver transistor operated in a linear region for obtaining light emission by the light-emitting element so that shrinkage can be easily observed.

FIGS. **47B** and **47C** are photographs showing a light-emitting state after 1000 hours elapsed after the preservation

test was started. FIG. **47B** shows a light-emitting state when the driver transistor operated in the saturation region, and FIG. **47C** shows a light-emitting state when the driver transistor operated in the linear region. FIGS. **47D** and **47E** are photographs showing a light-emitting state after 1500 hours elapsed after the preservation test was started. FIG. **47D** shows a light-emitting state when the driver transistor operated in the saturation region, and FIG. **47E** shows a light-emitting state when the driver transistor operated in the linear region.

Even after 1000 hours after the preservation test was started, shrinkage was not observed and light was emitted from the entire surface. After 1500 hours elapsed, slight shrinkage was observed (see the lower portion in FIG. **47E**). Note that the display is dark in FIGS. **47B** and **47D** as compared to that in FIG. **47A**. However, the preservation test hardly reduced the current efficiency of the light-emitting element, which suggested that the cause of the reduction in luminance is not degradation of the light-emitting element. A shift in the characteristics of the transistor, for example, probably reduced the luminance. It is unlikely that the reduction in luminance was caused by the hot press.

As shown by the results in this example, owing to one embodiment of the present invention, shrinkage was not observed even after 1000-hour preservation at high temperature and high humidity. It can be presumed that entry of moisture and the like through an end portion of the light-emitting device can be inhibited and high reliability can be achieved without impairing display quality of the light-emitting device.

#### REFERENCE NUMERALS

**10**: light-emitting device, **201**: formation substrate, **203**: separation layer, **204**: functional layer, **205**: insulating layer, **206**: functional layer, **207**: bonding layer, **208**: conductive layer, **209**: partition, **221**: formation substrate, **223**: separation layer, **225**: insulating layer, **226**: functional layer, **242**: partition, **244**: temporary sealing layer, **246**: projection, **251**: substrate, **253**: bonding layer, **254**: bonding layer, **256**: functional layer, **257**: bonding layer, **259**: substrate, **301**: display portion, **302**: pixel, **302B**: sub-pixel, **302G**: sub-pixel, **302R**: sub-pixel, **302t**: transistor, **303c**: capacitor, **303g(1)**: scan line driver circuit, **303g(2)**: imaging pixel driver circuit, **303s(1)**: image signal line driver circuit, **303s(2)**: imaging signal line driver circuit, **303t**: transistor, **304**: gate, **308**: imaging pixel, **308p**: photoelectric conversion element, **308t**: transistor, **309**: FPC, **311**: wiring, **319**: terminal, **321**: insulating layer, **328**: partition, **329**: spacer, **350R**: light-emitting element, **351R**: lower electrode, **352**: upper electrode, **353**: EL layer, **353a**: EL layer, **353b**: EL layer, **354**: intermediate layer, **360**: bonding layer, **367BM**: light-blocking layer, **367p**: anti-reflective layer, **367R**: coloring layer, **390**: input-output device, **501**: display portion, **505**: input-output device, **505B**: input-output device, **509**: FPC, **589**: insulating layer, **590**: flexible substrate, **591**: electrode, **592**: electrode, **593**: insulating layer, **594**: wiring, **595**: touch sensor, **597**: bonding layer, **598**: wiring, **599**: connection layer, **701**: flexible substrate, **703**: bonding layer, **705**: insulating layer, **711**: flexible substrate, **713**: bonding layer, **715**: insulating layer, **804**: light-emitting portion, **806**: driver circuit portion, **808**: FPC, **814**: conductive layer, **815**: insulating layer, **817**: insulating layer, **817a**: insulating layer, **817b**: insulating layer, **820**: transistor, **821**: insulating layer, **822**: bonding layer, **823**: spacer, **824**: transistor, **825**: connector, **830**: light-emitting element, **831**: lower electrode,

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832: optical adjustment layer, 833: EL layer, 835: upper electrode, 845: coloring layer, 847: light-blocking layer, 849: overcoat, 856: conductive layer, 857: conductive layer, 857a: conductive layer, 857b: conductive layer, 2000a: upper plate, 2000b: lower plate, 2005a: cushioning material, 2005b: cushioning material, 2100a: substrate, 2100b: substrate, 2101: substrate, 2102: projection, 2102a: projection, 2102b: projection, 4001: first substrate, 4002: light-emitting portion, 4003: signal line driver circuit, 4004: scan line driver circuit, 4005: region, 4006: second substrate, 4018: FPC, 4018a: FPC, 4018b: FPC, 7000: display portion, 7001: display portion, 7100: mobile phone, 7101: housing, 7103: operation button, 7104: external connection port, 7105: speaker, 7106: microphone, 7200: television set, 7201: housing, 7203: stand, 7211: remote controller, 7300: portable information terminal, 7301: housing, 7302: operation button, 7303: data, 7304: data, 7305: data, 7306: data, 7310: portable information terminal, 7320: portable information terminal, 7400: lighting device, 7401: stage, 7402: light-emitting portion, 7403: operation switch, 7410: lighting device, 7412: light-emitting portion, 7420: lighting device, 7422: light-emitting portion, 7500: portable information terminal, 7501: housing, 7502: display portion tab, 7503: operation button, 7600: portable information terminal, 7601: housing, 7602: hinge, 7650: portable information terminal, 7651: non-display portion, 7700: portable information terminal, 7701: housing, 7703a: button, 7703b: button, 7704a: speaker, 7704b: speaker, 7705: external connection port, 7706: microphone, 7709: battery, 7800: portable information terminal, 7801: band, 7802: input-output terminal, 7803: operation button, 7804: icon, 7805: battery, 9700: automobile, 9701: car body, 9702: wheels, 9703: dashboard, 9704: light, 9710: display portion, 9711: display portion, 9712: display portion, 9713: display portion, 9714: display portion, 9715: display portion, 9721: display portion, 9722: display portion, 9723: display portion, 9801: housing, 9802: housing, 9803: display portion, 9804: display portion, 9805: microphone, 9806: speaker, 9807: operation key, 9808: stylus, 9821: housing, 9822: display portion, 9823: keyboard, and 9824: pointing device.

This application is based on Japanese Patent Application serial no. 2014-212438 filed with Japan Patent Office on Oct. 17, 2014 and Japanese Patent Application serial no. 2014-257197 filed with Japan Patent Office on Dec. 19, 2014, the entire contents of which are hereby incorporated by reference.

The invention claimed is:

1. A light emitting device comprising:
  - a light emitting portion comprising:
    - a first flexible substrate;
    - a second flexible substrate; and
    - a first functional layer provided on the first flexible substrate;

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a non-light emitting portion comprising:
 

- a region having a driving circuit portion; and
- a region having a conductive layer; and

 the driving circuit portion comprising:
 

- the first flexible substrate;
- the second flexible substrate; and
- a second functional layer provided on the first flexible substrate,

wherein the conductive layer is provided on the first flexible substrate,

wherein the first functional layer comprises a light emitting element,

wherein the second functional layer comprises a transistor, wherein the conductive layer is electrically connected to an FPC,

wherein the non-light emitting portion is provided outside the light emitting portion along four sides of the first flexible substrate,

wherein the conductive layer is provided on one of four sides of the first flexible substrate,

wherein the second functional layer is provided between the first functional layer and the conductive layer, and

wherein at one of four sides of the first flexible substrate the distance between the first flexible substrate and the second flexible substrate in the non-light emitting portion is smaller than the distance between the first flexible substrate and the second flexible substrate in the light emitting portion, and

wherein the distance between the first flexible substrate and the second flexible substrate in the driving circuit portion is smaller than the distance between the first flexible substrate and the second flexible substrate in the light emitting portion.

2. The light emitting device according to claim 1, wherein at two of four sides of the first flexible substrate the distance between the first flexible substrate and the second flexible substrate in the non-light emitting portion is smaller than the distance between the first flexible substrate and the second flexible substrate in the light emitting portion.

3. The light emitting device according to claim 1, wherein in a region where the distance between the first flexible substrate and the second flexible substrate in the non-light emitting portion is smaller than the distance between the first flexible substrate and the second flexible substrate in the light emitting portion, the first flexible substrate or the second flexible substrate comprises a concave portion.

4. The light emitting device according to claim 1, wherein in a region where the distance between the first flexible substrate and the second flexible substrate in the non-light emitting portion is smaller than the distance between the first flexible substrate and the second flexible substrate in the light emitting portion, each of the first flexible substrate and the second flexible substrate comprises a concave portion.

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